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JOHN M. CLARKE, Director

Museum bulletin 119

GEOLOGY OF THE ADIRONDACK MAGNETIC IRON ORES

BY

DAVID H. NEWLAND

WITH A REPORT ON THE

MINEVILLE-PORT HENRY MINE GROUP

BY

JAMES F. KEMP

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New York State Education Department
Science Division, December 7, 1907

Hon. Andrew S. Draper LL.D.
Commissioner of Education

SIR: I communicate herewith, for publication as a bulletin of the State Museum, a timely treatise on the iron ores of the Adirondack mountains prepared by David H. Newland, Assistant State Geologist, to which is attached a special report on the deposits at Mineville, the result of many years of expert investigation by Prof. James F. Kemp.

Very respectfully
JOHN M. CLARKE
State Geologist

State of New York
Education Department
COMMISSIONER'S ROOM

Approved for publication this 7th day of December 1907

A. S. Draper

Commissioner of Education

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INTRODUCTION

The description of the Adirondack magnetites has been prepared in partial fulfilment of a plan to give an account of the iron ore deposits throughout the State. Field work was started in the Adirondacks in 1905 and has been carried on, as opportunity offered, during each succeeding season. It is hoped to complete the investigation of the other ore-bearing regions in the near future.

In the present report Prof. James F. Kemp has contributed the part relating to the important Mineville deposits, a section which he has recently mapped in connection with the geological investigation that is being carried on in the region under direction of the State Geologist.

The Adirondack region of crystalline rocks affords a variety of iron ores differing in their character and geological surroundings. Those found in sufficient abundance to be exploitable commercially may be classified under the main groups — (1) nontitaniferous

magnetites, (2) titaniferous magnetites, and (3) hematites. Of the three classes the nontitaniferous magnetites are the characteristic product of the region and have afforded by far the greater part of the output.

The occurrence of limonite deserves some notice, perhaps, though it can hardly be considered as an available resource at the present time. It is limited to surficial accumulations of impure bog ore doubtless derived from solution by ground water of the iron minerals that accompany the crystalline rocks. The ore is only occasionally found in deposits of any size and is then usually too lean to be marketable. It has been exploited on a small scale at times when conditions were specially favorable.

The two kinds of magnetites mentioned form the basis of the present report. They are quite distinct in respect to commercial considerations, as well as in the particulars of their geological associations and local distribution, wherefore it has been thought advisable for purposes of description to place them in separate divisions.

The hematite ores are practically confined to a single district on the west side of the Adirondacks. They have been mined for over 50 years and still supply a considerable output. They occur within metamorphosed Precambric sediments, mainly quartzose schists and limestones, where they have been formed by a process of chemical replacement. Their detailed description is reserved for a future paper. An isolated deposit of hematite, the only one that has been worked outside of the western district, is found near Fort Ticonderoga, on Lake Champlain, the particulars of which are given on a subsequent page of the present report.

The magnetite deposits of the Adirondacks have furnished altogether not less than 35,000,000 tons of commercial ore, an output that ranks them among the more important sources of this class of ores in the country. They have been exploited almost continuously for the past century, the earliest operations in the Champlain valley dating back to about 1800. Though some deposits have been practically exhausted by past operations, these are mostly the smaller ones, many of which would not repay working under existing circumstances. The larger mines now operated can continue along present lines for an indefinite period, so far as it is possible to judge their ore reserves.

A diminished ore supply, in fact, is of less concern for the future progress of mining, than the possible recurrence of a period of inactive demand for the ores such as has been felt at different times during the past. It is believed, however, that the industry

is on a firmer basis than ever before, due to the improved methods of preparing the product for the market. By the addition of milling plants to the installations, the mines are now able to ship their output in the form of concentrates, which contain smaller amounts of phosphorus and sulfur and higher percentages of iron than the crude material formerly marketed. The concentrates are in wide demand for mixture with the leaner ores of other districts and command a price above the average.

While the local charcoal industry which had long been the support of many small workings was completely extinguished during the depression of the last decade, there are now two coke furnaces in operation locally on Adirondack ores. The furnace recently built at Standish, Clinton co., manufactures a superior grade of low-phosphorus iron from the Lyon Mountain concentrates. The Port Henry furnace is run mainly on foundry irons, using the Mineville ores. The surplus product of the mines from these operations is sold to furnaces elsewhere in the State and in Pennsylvania.

The titaniferous magnetites which hitherto have been neglected almost completely may add materially to the output of the region in the near future. Their development is already in prospect at Lake Sanford, where there are enormous bodies of the ores, exceptionally situated for convenient working. The ores possess important advantages in their low phosphorus and sulfur, though the titanium content has been generally regarded as presenting difficulties to their reduction in the blast furnace. Under the present management of the enterprise at Lake Sanford a thorough test of the question as to their adaptability may be expected.

Acknowledgments. The courtesies extended by the mining companies and others interested in the development of the Adirondacks have been of invaluable aid in the preparation of this report. Much of the information relating to ore analyses, mine maps and sections, magnetic surveys, drill records, etc. has been secured through their agency. Some of those who have contributed in this way and to whom special recognition is due are: Messrs S. Norton, superintendent, and S. Le Fevre, engineer, of Witherbee, Sherman & Co., Mineville; W. T. Foote, Port Henry; J. N. Stower, Plattsburg; H. H. Hindshaw, New York, at one time geologist for the Delaware & Hudson Co.; N. V. Hansell, New York, formerly engineer at Lyon Mountain; C. S. Hurd, New York; W. L. Cumings, geologist for the Bethlehem Steel Co., South Bethlehem, Pa.; M. H. Newman, Madison, Wis.; and the Oliver Iron Mining Co., Duluth, Minn.

Part I

SKETCH OF THE GEOGRAPHY AND TOPOGRAPHY OF THE ADIRONDACKS

Under the Adirondack region is included the area of crystalline rocks of northern New York that is approximately bounded by the Mohawk valley on the south, the Black and St Lawrence rivers on the west, the St Lawrence plain on the north and the Hudson-Champlain valley on the east. Roughly rounded in outline it has an average diameter of 125 miles, and a surface of about 12,500 square miles. Within its limits lie nearly all of Essex, Warren, Hamilton and Herkimer counties and portions of Washington, Clinton, Franklin, St Lawrence, Jefferson, Lewis, Oneida, Fulton and Saratoga counties.

The region is a well defined physiographic unit. The Adirondacks and their foothills cover the whole area, forming an uninterrupted highland. They are composed mainly of long parallel ridges, separated by longitudinal valleys, and arranged in series or *en echelon*, with a prevailing northeasterly trend. Toward the borders the ridges gradually fall off and are succeeded by the bordering uplands which are constituted of outward sloping Paleozoic strata. On the east, however, they terminate more or less abruptly against the Lake Champlain trough, with but a narrow and interrupted fringe of sediments on that side.

The surface is diversified throughout, but not specially rugged except in the eastern central portion. Here the ridges are massed into mountain groups that stand out prominently by reason of their bold sculpture and elevation. Essex and southern Clinton counties contain most of the high elevations. The Mt Marcy group, the highest, has a few peaks rising 5000 feet or a little more, and there are many others with peaks above 4000 feet. The surface has a general, but not uniform, slope radially away from the central group, as will be observed from the directions taken by the streams. The drainage courses are influenced to some extent, however, by the general northeast-southwest alinement of the ridges.

The western part of the region, in St Lawrence county, shows a more subdued topography than other sections. It is a plateau broken by gentle ridges and open valleys, with occasional elevations rising a few hundred feet above their surroundings. The surface falls by gradual stages from the interior, which stands at about

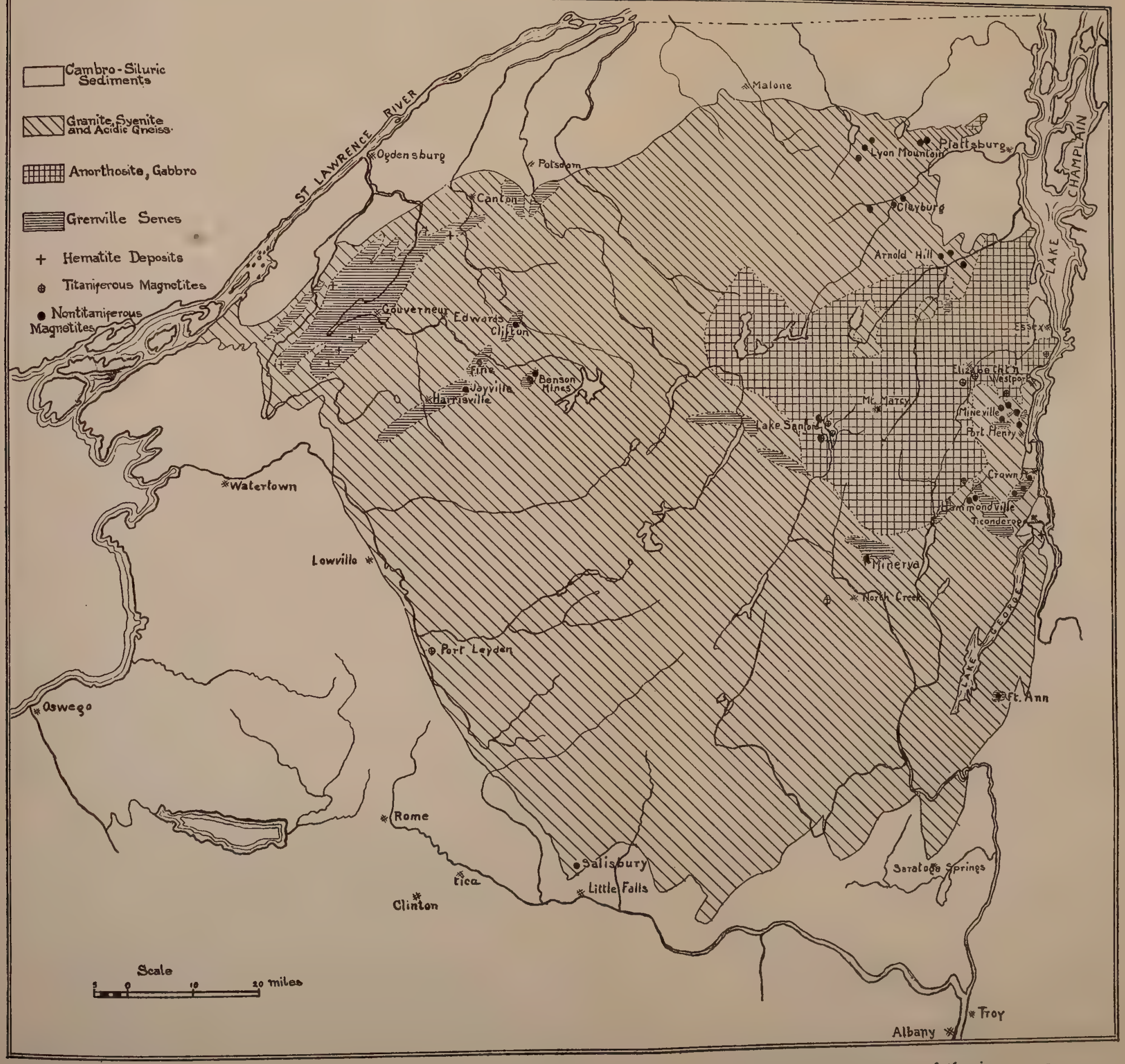


Fig. 1 The Adirondack region. Distribution of the principal geologic formations and occurrence of the iron ores

2000 feet, to the St Lawrence. The valley of the St Lawrence in this section has been worn down through the Paleozoic strata exposing the underlying crystallines in belts that extend to the river itself.

The history of the Adirondack topography is very involved. The mountains were upraised and folded long before Potsdam time, while they have been since subjected to long cycles of erosion and to renewed uplifts. The whole region appears to have been planed nearly level in the early Cambric period. It probably participated in the general Appalachian upheaval and has subsequently undergone more or less movement. Local faults have modified the erosional features, giving rise to abrupt rock scarps, serrated ridges which appear to be due to block tilting, and to wild passes and gorgelike valleys. The numerous belts of crystalline limestone that are interfolded with the other crystallines have also influenced the development of relief by their more rapid wear. The valleys floored by the limestone always have a rounded open character, in contrast with the usual narrow steep sided valleys found in the gneiss.

The Labrador ice sheet invaded the Adirondacks from the northeast and north, scoured the ridges to the summits and removed the products of rock weathering that must have accumulated in great thickness during the long period in which the region had been exposed to subaerial decay. Residual sands and clays from the decomposition of rocks in place are practically absent. In turn the ice spread over the region enormous quantities of transported materials—boulders, gravels, sands and clays. The preglacial valleys are often buried beneath hundreds of feet of such materials. It is to obstructions of this kind that many of the lakes, which afford one of the most attractive scenic features of the Adirondacks, owe their existence.

The mineral deposits constitute one of the main industrial resources of the region. They are perhaps second in importance only to the forests, as measured by value of the output. In addition to the iron ores, there are workable deposits of talc, graphite, garnet, feldspar and pyrite in different parts of the region. The quarry materials, of which there are inexhaustible supplies, include granite, syenite, anorthosite, trap, limestone and marble, suitable for building, construction or ornamental purposes.

GENERAL GEOLOGY

Principal publications. The geology of the Adirondacks was investigated in the early part of the last century by Prof. E. Emmons under commission of the Natural History Survey of New York State. The final report of Emmons, which was published in 1842, contains a vast collection of observations on the topography, rocks, stratigraphy and mineral resources of the region, constituting a valuable reference work to this day. The notes on the iron ores and the iron mining industry are commendable for their detail and accuracy. Professor Emmons considered the rocks to be mainly "primary" and divided them into the classes of unstratified, stratified and subordinate. Among the unstratified rocks he grouped granite, hypersthene rock (anorthosite), limestone, serpentine, and rensselaerite. The stratified class included gneiss, hornblende (hornblende gneiss and amphibolite), syenite and talc. The subordinate rocks were porphyry, trap, magnetite and specular iron ores. The stratigraphic sequence of the formations received little attention as, indeed, the question involved problems that could scarcely be met by the methods and opportunities which were at Professor Emmons's disposal.

A paper by C. E. Hall, published in the report of the New York State Museum for 1878, contains a description of some of the iron ore deposits of the eastern Adirondacks. The ores are stated to be associated with the following rock groups: Lower Laurentian magnetic iron ore series; Laurentian sulfur ore series; and the Upper Laurentian, or limestones and Labrador series, with titanic iron ores. In a note to the article the classification is amended by placing the limestones in a separate group with an unconformity at their base where they rest upon the Upper Laurentian.

In the last 15 years a geological investigation of the Adirondacks, wider in scope than any previously undertaken, has been in progress under the direction of the State Geologist. The field work has been carried out principally by Prof. J. F. Kemp, C. H. Smyth jr, and H. P. Cushing. Their efforts until recently have been directed toward a general reconnaissance as a preliminary to a detailed survey which was necessarily deferred until accurate base maps could be prepared. The results have appeared from time to time in the bulletins and reports of the New York State Museum. Much has been done to clear up the main problems connected with the lithologic and stratigraphic relations of the rocks, and it may be said that the principles for the interpretation of the geology of the

region are now fairly well defined. Professor Kemp has worked in the eastern section including Essex, Warren, and Washington counties and adjacent territory. Professor Cushing has been mainly occupied with the northern region of Clinton, Franklin and Hamilton counties; while Professor Smyth has worked in St Lawrence, Jefferson and Lewis counties on the western side.

With the publication of topographic sheets for parts of the region by the United States Geological Survey in cooperation with the State Engineer it has been possible recently to undertake the preparation of detailed geologic maps. Thus far Professor Cushing has reported upon the geology of the Little Falls quadrangle in Herkimer county and the Long Lake quadrangle in Hamilton county and Dr I. H. Ogilvie has surveyed and described the Paradox Lake quadrangle in Essex county. Field work has been completed also upon one or more quadrangles in Essex, Hamilton and St Lawrence counties.

Outline of geology

The rocks comprising the Adirondack region are almost exclusively Precambric in age. The bordering Paleozoic strata are sometimes found well within the interior, but they occur in disconnected exposures which altogether comprise an inconsiderable portion of the total area. Their base, the Potsdam sandstone, rests unconformably upon the Precambric crystalline rocks. The unconformity marks a very long time gap. Before the deposition of the Potsdam the Precambric rocks had been modified by repeated dynamic action, had been uplifted, intruded, and finally exposed to erosive influences that removed great thicknesses from their surface.

The Precambric rocks, with the exception of small dikes that were of late Precambric intrusion, have all been subjected to powerful compression and in many cases have been greatly changed by metamorphism. Among them there are representatives which were undoubtedly original sediments, but these have almost wholly lost the characteristic features of such rocks so that their recognition is at times a matter of extreme difficulty, if indeed they can now be identified at all. The metamorphism took place while they were deeply buried, under conditions of pressure and heat that brought about a recrystallization of the fragmental components; and what were once sandstones, shales and calcareous sediments now have the characters of gneisses, schists and coarsely crystalline limestones.

The inference as to their origin is more readily apparent in the case of the limestones and schistose types than in reference to the more massive gneisses, for which the field evidence alone is seldom determinative.

Plutonic igneous masses invaded the region at different times during the Precambric period. They have broken up the sedimentary rocks into isolated areas, injected them with their materials and blended with them along the contacts. Subsequent compression has converted them into gneisses which are often hard to distinguish from those of the sedimentary class. A later manifestation of igneous activity led to the intrusion of dike rocks.

While a great part of the crystallines can be differentiated into the two classes of igneous and sedimentary derivatives, there are considerable areas of gneisses whose origin has not been fully established. Their relationships have been obscured by profound alteration, leaving little evidence as to their original nature. It is in connection with these rocks that the principal stratigraphical problems remain to be solved.

According to the classification generally employed for Precambric rocks, the sedimentary gneisses fall within the Grenville series. If any rocks exist in the region which antedate the oldest sediments of that group, they are probably to be found among the gneisses previously mentioned.

Sedimentary, or Grenville, series. So far as known, the sedimentary derivatives are the oldest rocks in the Adirondacks. They possess much similarity in their development and individual constitution to the Grenville series of Canada, with which they are now generally correlated as the nearest equivalent in age. They are believed to be ancient water deposits and if so must have been laid down upon some floor of still older rocks that have not yet been definitely recognized. Little is known as to the thickness of the series, though from the facts of their distribution it is concluded that they must have been originally very thick. The variation in composition, from original calcareous and magnesian deposits to shales and sandstones and probably coarse conglomerates, as well, is such that it can be explained only by wide-reaching changes in the processes of accumulation that require long lapses of time. Neither the base nor the top of the series has been identified.

Limestone. The limestones have the crystalline texture of marbles, they range from nearly pure lime carbonates to magnesian limestones and dolomites. They are always impregnated by foreign minerals that have been formed out of the carbonates and the

included impurities by regional and contact metamorphism. Pyroxene, amphibole, mica, graphite, pyrite and scapolite are common associates. With an increase in the proportion of the silicate minerals, the limestones pass into micaceous, pyroxenic or amphibole schists. By secondary alteration of the pyroxene a serpentinous limestone or more rarely a massive serpentine may be developed.

The limestones and associated schists are found generally in long narrow belts bordered by the sedimentary gneisses. They are most widespread on the northwestern side of the Adirondacks in St Lawrence, Jefferson and Lewis counties. Four main belts, with a length of from 15 to 35 miles, and a great number of smaller ones have been mapped in this region. On the east side they occur most abundantly in Essex county, but they are here less extensive. In the interior and on the northern and southern borders, the limestones are encountered in disconnected patches, occasionally interfolded with the igneous rocks in which they were, no doubt, involved during the intrusion.

Gneiss. The sedimentary gneisses are an extremely varied class. Their many phases comprise light colored acid types made up purely of quartz and feldspar, gray or dark gneisses in which the ferromagnesian minerals are represented more or less abundantly, and black basic varieties with only subordinate feldspar or quartz. Wide differences in composition are often observable within the limits of a single outcrop, particularly in passing across the foliation. The transitions from one variety to another take place quickly and lend the appearance of a banded arrangement comparable to that of bedding among unaltered sediments. Still there are districts in which the gneisses show a fair degree of uniformity, and their relations are only to be established after careful investigation in the field and laboratory. The presence of graphite is common and suggestive. Garnet, sillimanite and pyrite are also characteristic minerals. Where pyrite occurs the beds weather rapidly, taking on a peculiar rusty appearance. The texture of the gneisses is always granular, as a rule finely so, due to the intense crushing they have undergone.

The distribution of the sedimentary gneisses corresponds in a general way to that of the limestones, being most widely developed on the borders of the region. They occur, however, over considerable areas where limestone may be relatively scarce. In the northern Adirondacks, Cushing has found them to be of small importance, as the main formations are igneous or of so question-

able character that their relations can not be stated definitely. In St Lawrence county the sedimentary gneisses are widespread in the vicinity of the limestone belts above mentioned. They have also been traced by the writer to the east toward the interior as far as Cranberry lake. They are the country rock of the magnetite deposits in this section. Professor Kemp has described gneisses of sedimentary type in southern Essex, Warren and Washington counties. As to the southern border of the Adirondack region, little has been made known but it is probable that the sedimentary gneisses are well represented.

Amphibolite. Involved with the limestones and gneisses, and less frequently with the plutonic igneous rocks, are small masses of amphibolite, dark colored and consisting essentially of hornblende and feldspar. They often have a rusty appearance that betrays the presence of pyrite. Their occurrence in tabular bands, which may be persistent for considerable distances, is suggestive of dikes and it is quite likely that they are in part metamorphosed diabases or gabbros. This view is particularly applicable to examples that have a plagioclase as the principal feldspar constituent, but can hardly be accepted for occurrences in which the hornblende is associated with orthoclase, as is not infrequently the case. For these the derivation from a magnesian shale seems to be the more obvious explanation.

Quartzite. As a somewhat uncommon type of the Precambric sediments, may be mentioned the occurrence of quartzite which has been made known on both the eastern and western borders of the Adirondacks.

In Essex county, Professor Kemp has noted several localities where this undoubted fragmental rock occurs. It nearly always carries graphite, pyrite and sillimanite and sometimes feldspar and mica. At Hague on Lake George and at the village of Graphite, 5 miles west from Hague, a bed up to 15 feet thick is included between a garnetiferous sillimanite gneiss. At Rock pond between Graphite and Hammondville, there is another area; while in the town of Lewis, 3 miles south of Elizabethtown, exposures show a thickness of 100 feet of quartzite overlain by graphitic gneiss.

Professor Smyth has found the same rock in St Lawrence county. On Wells island in the St Lawrence river a white vitreous quartzite is exposed along a ridge for nearly 5 miles with an estimated thickness of 500 feet. It is associated with schist and both are cut out by granite gneiss which forms the southern part of the island. A second belt occurs between Redwood and Rossie, the quartzite

being interbedded with limestone and hornblende, mica and pyroxene schists. The St Lawrence county quartzites contain feldspar and mica, but are not so graphitic as those of Essex county, where they have been exploited.

The quartzites are no doubt ancient sandstones that have been hardened by recrystallization of the quartz particles; they may be considered, therefore, to represent the extreme silicious phase of Precambric sedimentation.

Gneisses of undetermined relationship. The recent work in the Adirondack region has disclosed the existence of certain gneisses of obscure character. While more detailed investigation may resolve them into elements which can be classed with the igneous or sedimentary series, they have been found so far to have no well defined connection with either.

Saranac formation. The principal area of these gneisses seems to be on the northern borders in Clinton and Franklin counties. Professor Cushing has described a belt that extends along the Paleozoic contact for a distance of 70 miles. The rocks are mainly red acid gneisses, composed of alkali feldspar, which is usually microperthite, and quartz, with small amounts of hornblende and biotite. They are thus mineralogically related to the granites, but differ from the latter in their textures which are often finely granular or without the definite arrangement that characterizes igneous rocks in their original state of consolidation from a molten condition. Besides the acid gneisses a gray variety consisting of pyroxene and feldspar (orthoclase and plagioclase) and dark hornblende gneisses or amphibolites occur as bands or larger masses. Of the Grenville rocks there are very few exposures throughout the entire belt. The gneisses as a whole correspond in composition quite closely to a series of igneous rocks grading from granites through syenites and diorites to gabbros, though the comparison has not been substantiated fully by chemical analyses.

Professor Cushing is inclined to regard them as an older series than the recognized intrusives and has proposed to group them collectively as the Saranac formation, a name suggested by their occurrence along Saranac river. Concerning their possible position among the Precambric rocks of the Adirondacks, Professor Cushing points to the similarity which they show to the basal gneisses in other regions and more specially the so called Ottawa gneiss of Canada; while he seems to favor the view that they represent the original floor on which the Grenville rocks have been deposited, he does not regard the proofs for this explanation to be fully established.

Within the belt are comprised several large magnetite deposits, including those at Lyon Mountain and vicinity, the Arnold hill and Palmer hill bodies, and a number of smaller ones. Opportunity has been afforded the writer of studying the gneisses in the field as well as to compare them with the rocks of other mining districts. At many localities within the belt have been found undoubted representatives of the igneous rocks. The acid gneisses particularly contain cores which are coarsely textured, even porphyritic, and in other respects are analogous to the characteristic Adirondack granites; the coarse phases can be traced at times by gradation into fine grained gneissoid rocks which are evidently only crushed portions of the same mass. It seems probable that the granitic series will be found to abound throughout the belt, yet there are large areas of gneiss that can not be satisfactorily correlated on the basis of present knowledge.

Igneous intrusions. The plutonic igneous rocks of the Adirondacks can be divided into four great groups, viz: anorthosite, gabbro, syenite and granite. In their normal development the individual groups are well contrasted by their physical appearance, as well as by the peculiarities of their chemical and mineral composition. They are all connected, however, by a series of intermediate rock types, presenting a variation scarcely interrupted from the acid to the basic members. This close relation between the groups is generally recognized to be an original feature, due to a common derivation from a continuous magma in the interior. By repeated segmentation and intrusion the magma has given rise to the rock series now existing at the surface.

Anorthosite. The anorthosite is the earliest in point of time of the intrusions mentioned. Its occurrence in the Adirondacks was made known by Professor Emmons who described it under the name of hypersthene rock. That he recognized its igneous nature is clearly evidenced by the fact that in his report it is placed among the unstratified class of rocks, though the name he used has given way to the more appropriate one which emphasizes the feldspathic component. Hypersthene plays a very subordinate role in the composition of the Adirondack anorthosite. The rock forms the central massive of highest uplifts. It is exposed over an area that is roughly triangular in shape with its base on the north along the Essex-Clinton county border, extending west from Lake Champlain for over 50 miles, and its apex in southern Essex county near the Warren county line. The area probably exceeds 1200 square miles. There are some belts of gneisses and crystalline

limestone within the area, probably entangled masses borne up on the surface of the intrusion, but in the main the anorthosite is unbroken by other rocks. Small outlying exposures of anorthosite have beeen found on the northern and southern borders, the most remote being the Rand hill intrusion near Dannemora, Clinton co., and the one near Bakers Mills, Warren co., both of which lie some 20 miles distant from the proximate portion of the principal area.

In its normal development the anorthosite consists of little else than feldspar which is generally a blue labradorite. This mineral occurs as a rule in large interlocking crystals, giving the rock a very coarse texture like that of porphyritic granites. The accessory minerals include augite, hypersthene, hornblende, ilmenite and magnetite. While usually constituting a small percentage of the rock, the ferromagnesian silicates may assume such importance as to mark a gradation toward or even a complete transition into the gabbros. With the increase in the proportion of these minerals, there is also a change in the texture, which becomes finer by diminishing the size of the feldspar and shows the characteristic mottled aspect of gabbroic rocks. There are innumerable places within the area where this variation is to be found. The gabbro type, however, falls far short of the wide distribution of the feldspathic phase, being limited to patches and dikelike bands in the latter. By compression the anorthosite has become laminated, specially in the bordering zones where it often shows a thoroughly gneissoid appearance. The feldspar crushes down to a white mass of granules, in which remnants of the original blue feldspar may usually be seen. The granulation is accompanied by the development of garnet in the form of pink crystals surrounding the dark silicates.

Gabbro. This rock stands in close relation to the anorthosite. It is abundant only within the area occupied by the latter or in close proximity thereto. The gabbro is a black, very dense aggregate of labradorite, augite, hypersthene and ilmenite or magnetite, with olivine as a somewhat uncommon constituent. It seems to have been a later differentiation of the magma which has given rise to the anorthosite as it sometimes cuts the latter intrusively. The gabbro inclusions which grade into the anorthosite are, however, contemporaneous segregations.

The limited masses of gabbro have sometimes been so thoroughly metamorphosed as to assume the character of amphibolites. The presence of unchanged pyroxene and basic plagioclase feldspar

furnishes a clew to the derivation of such amphibolites, in distinction from those which are of sedimentary origin.

Syenite. The Adirondack syenite constitutes an abnormal variety of that rock, and was not recognized as such until recently. Mineralogically it occupies a middle place between the gabbroic rocks and the granites. A green augite is nearly always the chief dark constituent, but hornblende and hypersthene may be present. The feldspar is commonly microperthite. Orthoclase, oligoclase, quartz and magnetite are the more important of the other minerals. The rock nearly always has a greenish color, varying from light to dark shades. When there is a considerable proportion of the dark constituents, it resembles the gabbro so much as to be hardly distinguished in the field, a resemblance which is even closer in comparing gneissoid varieties of the two rocks. With the increase of those minerals there is apt to be a change also in the feldspars shown by the preponderance of the oligoclase over the alkali feldspars. It is not apparent, however, that the syenite ever merges completely into the gabbro, the evidence tending to show that the two are separate and distinct intrusions. On the other hand the acid types of the syenite pass into typical granite, as was first demonstrated by Professor Smyth.

The syenite occurs in local intrusions all through the Adirondacks outside of the anorthosite area. It is developed in great force in the northern section, specially in Franklin county, and is common in the eastern part though the different areas here have not yet been delimited. On the south side the Precambric outlier near Little Falls consists of syenite. The Diana-Pitcairn area on the northwest, described by Professor Smyth, deserves mention as affording the first evidence of the intrusive character of the rock and its lithologic relations.

Granite. The granites, with the derived gneisses, are the most frequent of all the intrusives. They are closely involved with the Grenville series and over large districts are the only igneous formation present. It has already been pointed out that they constitute an important factor in the belt of Saranac gneisses.

The granites are prevailingly light colored, gray or reddish rocks. Feldspar and quartz always predominate and may be practically the only minerals present. Hornblende granite seems to be more common than the mica varieties, while augite granite occurs as a variation of the syenite. It is only rarely that the intrusions have preserved their original massive character, a granulated cataclastic and gneissoid texture being the rule. In regions where compression

and crushing have been carried to an extreme, the resultant gneisses present most difficult problems to the geologist since they are often inextricably involved with the sedimentary gneisses.

The age of the granite intrusions relative to that of the other igneous rocks has been demonstrated in only a few cases. There is little question that some granites are later than the anorthosite and according to Professor Cushing even later than the syenite. Not improbably they may represent more than one period of intrusion.

Dike rocks. The dike rocks in the Adirondack region are mostly diabases. These are common in Clinton county, where they have been uncovered in large numbers in the mines, and to a lesser extent in Essex county. In the interior and on the southern and western sides they occur only rarely. The dikes seldom attain a thickness of more than 20 or 30 feet, the majority perhaps being less than 10 feet. A few dikes of syenite porphyry have been found in Essex and Clinton counties. The dikes cut all the formations previously described, but have not been found anywhere to intersect the Paleozoic strata. They belong thus to the Precambric. That they must have been intruded very late in Precambric time is indicated by the fact that they have undergone no appreciable metamorphism or compression in which the other crystalline rocks have participated.

Paleozoic sediments. The Paleozoic sedimentary strata, which are found on the edges and to a lesser extent in the interior of the Adirondacks, rest in nearly horizontal position upon the eroded surface of the crystallines. During the period of their deposition the region underwent a gradual subsidence that brought a continually increasing area, with the progress of time, below the level of the sea. The formations have at their base the Potsdam sandstone, while the highest member is the Utica slate.

The Potsdam is mostly an indurated sandstone or quartzite, coarse and conglomeratic near the bottom. It lies along the entire northern border but thins out nearly to disappearance to the south. The Beekmantown, or Calciferous, formation following the Potsdam consists of calcareous sandstone and limestone and is found on all sides except the western. In the Champlain region it attains its extreme thickness. The Chazy limestone, which is next in order, is confined to the Champlain valley. The Lowville, Black River and Trenton formations are made up of gray and black limestones, with shaly partings in the Trenton marking a transition into the Utica shale, the last of the series. They are mainly developed on the south.

Small areas of the sediments occur in the interior as far as 40 miles from the borders. In some instances they lie 1500 feet above sea level. They represent mere remnants of once continuous deposits which extended over most if not all of the Adirondacks. There is strong evidence that the submergence of the region was practically complete during Utica time. Since the close of that epoch the region has been above sea level, exposed to weathering and erosion, and has received no deposits except the sands, gravels and clays left by the glacial invasion and the more recent river detritus.

Structural features. The structures of the Precambric rocks as revealed by their present attitudes in the field have not been worked out for the Adirondack region, and even over the limited areas that have been studied and mapped with care the structural details in most cases have proved too confusing to be deciphered. There is abundant proof, however, that the rocks have undergone great compression and have been folded and faulted on an extensive scale.

One of the principal difficulties encountered in the study of the structural features is the extreme variability as to the evidences afforded by the rocks of their disturbance. The presence of foliated and gneissoid textures is a common characteristic but they are not always so apparent as to be a serviceable guide in the field.

Foliation is best developed in the dark sedimentary gneisses and schists. These rocks contain a considerable proportion of the ferromagnesian silicates — biotite, hornblende and pyroxene — which owing to their crystal habit would orient themselves most readily under compression. When the foliation is parallel to the original bedding planes, as seems to be the general case with these rocks, the records of dips and strikes afford unquestionable evidence for establishing the structure. The limestones have flowed and recrystallized so that they rarely show either foliation or traces of their former bedded structure.

In areas underlain by a complex of igneous and sedimentary formations it is seldom that any connected series of dip and strike observations can be made. There is some possibility that in the districts composed mainly of the Grenville series, such as on the west and south, a close study of the field relations may yield positive results.

The strikes and dips in any part of the region seldom remain uniform over more than a small area. The strike generally follows more or less closely the prevailing trend of the ridges, that is in a direction east of north, but it is subject to local variations of several degrees. The swings are gradual as would be expected in folded

rocks. The principal thrust has been evidently from the southeast or northwest. From the fact that the eastern section has undergone the greatest disturbance from its influence, the direction would appear to be from the southeast rather than from the opposite point.

The iron ore deposits afford many interesting examples of flexure. Originally they were probably straight tabular bodies formed previous to the dynamism that has affected the inclosing rocks. In some districts they have been very little disturbed, either along the strike or on the dip. In others as instanced by the deposits of Essex county, they have been flexed, twisted and made to assume the most intricate shapes, around which the walls have been closely molded.

The existence of faults can be demonstrated in many cases where the conditions are favorable for their detection, that is in areas made up of contrasted formations, and their presence is indicated elsewhere by topographic considerations. The probable close connection between the present surface conformation and faulting has been brought out more specially by Professor Kemp in his work in Essex county.

The main series of faults has a northerly trend, varying from nearly due north to northeast. It approximately parallels the longer axes of the ridges and tends to produce steep faces on the northwest and southeast sides. This faulting may have been responsible to some extent for the markedly uniform trend of the ridges and valleys. In some cases the latter appear to occupy a depressed strip between two parallel faults of this character.

A second series of faults, which has probably resulted from the movements initiated by the main series, trends away at variable angles, so that the ridges are divided into irregular blocks. Examples of such block faulting in which the displaced portions are more or less tilted form a characteristic feature of the interior Adirondacks.

The eastern and southern margins of the region have been extensively faulted. In Clinton county Cushing has found the Paleozoic strata to be frequently displaced by meridional faults, of which one in Chazy township along Tracy brook has a throw of at least 2000 feet, and cuts out the entire Beekmantown formation. Most of the faults in this section downthrow to the east. It would appear that the New York shore of the lower part of Lake Champlain is limited by a series of meridional breaks forming a basin tilted to the west. North of the Mohawk valley there are a number of displacements trending northeast across the dip of the Paleozoic

strata into the crystallines. As described by Darton they are normal faults with a downthrow to the east, amounting to 800 feet in the Little Falls fault and to 1600 feet in that at Hoffman. The faults cut the latest of the stratified rocks represented, the Utica shale.

An earlier period of faulting occurred in Precambric time, though the displacements can be distinguished from those of later age in but few cases. The ore bodies on Arnold hill have been broken by a system of cross faults, and along some of these diabase dikes have been intruded. The dikes are, as already stated, of late Precambric age. As they show no effects themselves of any disturbance, it would appear that the displacements occurred before their intrusion.

Part II

NONTITANIFEROUS MAGNETITES

General relations and distribution

The class of so called nontitaniferous magnetites includes the ores that are relatively free from titanium. The term nontitaniferous, it may be noted, is hardly an accurate one to apply to any of the Adirondack magnetites, since the presence of titanium has been shown to be almost universal in these ores. For practical purposes, however, the low-titanium magnetites may well come under such designation, since they carry an inconsiderable proportion of the element — usually but a fraction of one per cent — too small to have any notable influence on their metallurgical behavior. The titanium is traceable usually to the mineral titanite which is a common constituent of the wall rocks and is often intergrown with the magnetite. Its proportion is generally higher in crude ore than in concentrates, the titanite being removed to a greater or less extent by mill treatment.

The nontitaniferous magnetites are the most widespread of the Adirondack iron ores. They have been worked at a great number of localities distributed over different sections.

With some exceptions the deposits may be grouped, however, into two geographical regions. The first and more important is that lying on the eastern border of the Adirondacks within the Lake Champlain drainage basin. To this region belong the deposits of Washington county, the Hammondville and Mineville districts and the smaller mines of Essex county, and all of the mines of Clinton county aside from the Lyon Mountain group. The last named is the only one on the north side of the Adirondacks that has been exploited to any extent, though there are a few small bodies in Franklin county. The second region lies on the west side in St Lawrence county and includes the Benson, Jayville, Fine and Clifton deposits all lying in the same vicinity. The rest of the western border extending through Jefferson, Lewis and Oneida counties contains, so far as known, no deposits of size. On the south side the Salisbury mine of Herkimer county is the single representative.

Attention has been called by Smock and other writers to the fact that nearly all of the mines occur in the bordering zone and that comparatively few have been opened in the interior of the

Adirondacks. This is attributed to the more thorough exploration of the outer areas owing to the advantages they afford in regard to accessibility for prospecting and transport of the ore to the market. No doubt the explanation is a reasonable one and entitled to serious consideration. But it would seem not improbable that there is an underlying geological basis for the general distribution of the occurrences that may be brought out clearly when the region is mapped in detail. The present study has not been extended beyond the limits of the ore-bearing districts. The interior of the Adirondacks is occupied in part by the great anorthosite mass, within which the ores are all titaniferous. Of the extensive region to the west and south of this area to near the Adirondack borders little is known as yet concerning its geology.

By far the greater number of mines that have been worked, including all the important ores, are restricted to a few districts of comparatively limited area. The total surface embraced within these districts constitutes but a very small portion of the whole region. It is probable that future exploration when extended into the outlying areas will result in the addition of new deposits to the list; but it can hardly be expected that the discoveries will compare in importance with those already made. The favorable ground for development was sought out by the early prospectors who seem to have penetrated into the most remote parts in their search and to have made good use of the dip needle and compass, by which the location of highly magnetic bodies like these is a comparatively easy matter.

Character of the ores

The ores show great variation in their mineral and chemical composition. They range from impure lean varieties consisting of magnetite intermixed with the constituents of the wall rocks, such as quartz, feldspar, pyroxene, hornblende etc., to those made up of practically pure magnetite. The richest average from 60 to 70 per cent iron. They have been obtained principally from the Mineville district, where some large bodies have averaged 60 to 65 per cent iron and have afforded considerable quantities assaying above 65 per cent and even approaching closely the theoretical limit for magnetite which is 72.4 per cent. The Hammondville, Arnold hill and many other mines have yielded ores with 50 to 60 per cent iron. The magnetites that carry less than about 50 per cent iron

are generally considered too refractory for direct smelting; their utilization depends upon concentration, to which they are as a rule very adaptable. There are large bodies of such ores in the Lyon Mountain, Arnold hill and St Lawrence county districts. The lowest grade of milling ore that is worked carries about 35 per cent iron.

According to the percentage of phosphorus present, the magnetites may be subdivided into low-phosphorus, Bessemer and non-Bessemer grades. There is no well defined connection between the distribution of phosphorus and the nature of the ore occurrence. In some districts, as instanced by Mineville, both Bessemer and high-phosphorus ores have been produced from contiguous deposits, though generally the ores from any one district show a fair degree of uniformity in respect to the phosphorus. The leaner magnetites are apt to be lower in phosphorus than those having a high percentage of iron. The bulk of the low-phosphorus ores has been produced at Lyon Mountain; the present concentrates from this locality carry less than .01 per cent of that element with 65 per cent iron. The non-Bessemer ores range up to about 2 per cent phosphorus, corresponding to 10 per cent of apatite, which is the containing mineral. The Old Bed group of mines at Mineville has furnished most of this grade of ore.

The magnetites carry a variable proportion of sulfur, due to admixture with pyrite and more rarely pyrrhotite. The part played by these minerals in the composition depends upon the geological associates of the ore bodies, and a sharp line can be drawn generally between the class which carries any considerable proportion of them and the low-sulfur deposits. The presence of sulfur above a fraction of one per cent is confined mainly to the deposits that occur in the banded gneisses and schists of the Grenville series, which are themselves impregnated with pyrite. When the wall rock is an acid variety, corresponding to granite or syenite in mineral composition, sulfur exists only in minute quantity. Among the deposits belonging to the former class it is possible to find gradations from ores with fairly low sulfur to those in which the magnetite is replaced largely or almost completely by pyritic minerals.

Local variations in the ores frequently arise from the association of pegmatite which may carry magnetite in quantity to make it valuable. It has additional interest as affording a number of the rare minerals and many that attain unusual crystallographic development. Mineville and Lyon Mountain have yielded the

greatest variety of species. Professor Kemp[1] has listed the minerals from the former locality, with mention of their more important characters. The Lyon Mountain locality has been described recently in a detailed manner by H. P. Whitlock.[2]

As a rule the magnetites show little alteration or effects of weathering, and are quite fresh at the surface. The only chemical change at all common is oxidation with the formation of hematite. The latter is usually pseudomorphic showing the characteristic granular structure and octahedral parting of the magnetite—the form known as martite. It occurs sparingly in several deposits, but in quantity only on Arnold hill where the so called "blue" veins are practically solid hematite. The oxidation of magnetite to hematite is accomplished very slowly under ordinary atmospheric conditions, and it seems to have been induced in these deposits by some special agency connected probably with underground water circulations. There are bodies of unaltered magnetite in the same vicinity.

Shape of the deposits

The Adirondack deposits occur in a variety of forms such as are common to the magnetites found in gneisses and schists elsewhere. They have been designated by different writers as beds, veins, pods, shoots, lenses etc., depending upon their particular development in the locality investigated.

In general the bodies have a much greater extent along the strike and dip than at right angles thereto, and show a more or less lenticular form in horizontal section, wider at the middle and tapering toward either end. In some cases they are so prolonged in the direction of strike that they are better described as tabular bodies, their regularity of width being like that found in a bed or stratum, a resemblance that has been emphasized by some geologists as evidence of a sedimentary derivation. The tabular and elongated lenticular bodies are more abundant in the northern and western Adirondacks. The Lyon Mountain, Arnold hill and St Lawrence county districts afford examples. The greatest irregularity of form prevails in the eastern districts, particularly those of Essex county, where the deposits often exhibit a puzzling complexity of pinches, swells and sharply compressed folds not observable in other sections.

[1] Geology of the Magnetites near Port Henry. Amer. Inst. Min. Eng. Trans. v. 27. 1897.

[2] Minerals from Lyon Mountain. N.Y. State Mus. Bul. 107. 1907.

There can be no doubt that the form assumed by the ore bodies is conditioned by the structures of the inclosing rocks. When the latter are foliated to an extent that permits observations of dip and strike, the contours follow the changes closely, even the subordinate ones. This feature is least apparent in the gneisses of the igneous series, the structures of which are often only faintly indicated, and most evident in the banded gneisses and schists of the Grenville. The ores consequently must have been deposited before the great regional disturbances took place, or at least before the rocks received their present structural arrangement. They have passed through all the vicissitudes of squeezing, folding and other deformations that have been impressed upon their walls.

In their original condition the ore bodies were probably tabular masses, like those now existing in the regions of least disturbance. From such masses, a complete sequence may be traced into lenses, shoots and the more complicated structures that have been developed by operation of mechanical processes.

Associated rocks

There is no constant type or formation that is characteristic for the nontitaniferous ores as a whole. The wall rocks include gneisses of granitic, syenitic and dioritic composition, acid pyritic, garnetiferous gneisses, hornblende and biotite schists, amphibolites and occasionally crystalline limestones.

From considerations of their probable origin, they may be divided into (1) igneous derivatives and those closely allied to the characteristic intrusive masses of the Adirondacks; (2) members of the sedimentary or Grenville group. Nearly all of the magnetite-bearing rocks may be referred with a degree of certainty to the one or the other of the two classes. For a few occurrences, however, the evidences of relationships that have been found thus far are too obscure to admit any definite conclusions, though it is probable that the rocks are uniform with the others, rather than characteristic of a distinct class.

1 **Igneous group.** The more acid members of the igneous series constitute the country of the Clinton county mines, all of which occur within the belt of alkali-feldspar gneisses known as the Saranac formation. At Lyon Mountain, the country consists of a massive reddish variety composed of microperthite, oligoclase, green augite, hornblende and magnetite with a small amount of quartz. Mineralogically it lies on the border between the syenite and granite rock

groups, with local variations ranging through both. Its intrusive nature is evidenced by the penetration and absorption of an older formation, a hornblende schist which occupies limited belts in the vicinity, as well as by its pegmatitic and thoroughly massive phases.

The numerous deposits centering around Arnold hill and Palmer hill, in southern Clinton county, are inclosed by the same Saranac series. The Palmer hill ore body is particularly interesting, in that it consists of a magnetite band in a massive augite-biotite granite that carries fluorspar. This mineral forms an integral part of the ground mass, where it is associated with quartz and feldspar (microcline and orthoclase) reaching at times large proportions. Its presence can hardly be explained except by pneumatolytic action during the consolidation of the rock from a molten state. Fluorspar is a quite common mineral in the magnetites elsewhere, but usually in small quantities and limited, so far as observed, to pegmatite or vein material.

Syenite of the characteristic Adirondack type is represented in force in the Mineville group of mines. It has been shown by recent drilling to underlie the ore bodies in what seems to be a continuous mass. The rock is of greenish cast and is normally composed of microperthite, green augite, hornblende and magnetite, but through the addition of quartz and shrinkage of the ferromagnesian constituents, passes into a lighter reddish rock that is much like the varieties above described. This rock called the "21" gneiss in the earlier report of Professor Kemp, forms the hanging wall of the Old Bed group. Its relations to the underlying syenite, as well as the apparent differentiation of the latter into a dioritic phase, are brought out in the article by Professor Kemp included herewith.

A basic variety of augite-syenite constitutes the wall rock at the mine near Salisbury, Herkimer co., being a part of the intrusives in that region which reach southward from the Adirondacks into the Mohawk valley. The dark minerals (augite, hornblende and magnetite) constitute about 75 per cent of the rock in immediate contact with the ore, but away from the latter there is a gradual change into the normal syenite.

While the rocks from the different mine localities have not been chemically analyzed, the following tabulation of analyses taken from a recent report by H. P. Cushing[1] may be useful in showing the general range of the igneous series. The description of the

[1] Geology of the Long Lake Quadrangle. N. Y. State Mus. Bul. 115. 1907. p. 520.

specimens taken for analysis indicate close resemblances in many cases to the ore-bearing rocks. Professor Cushing has worked out the corresponding mineralogic composition and it will be of interest to note the relative quantities of magnetite present.

	1	2	3	4	5	6	7
SiO_2.....	54.10	59.70	61.01	62.85	63.45	66.72	68.50
Al_2O_3.....	17.45	19.52	15.36	16.80	18.38	16.15	14.69
Fe_2O_3.....	4.52	1.89	2.98	2.96	1.09	1.23	1.34
FeO.....	6.47	4.92	7.77	2.89	2.69	2.19	3.25
MgO.....	2.33	.78	.78	1.48	.35	.73	.26
CaO.....	6.17	3.36	4.05	3.24	3.06	2.30	2.20
Na_2O.....	3.81	5.31	3.68	4.09	5.06	4.36	3.50
K_2O.....	3.06	4.14	3.90	5.49	5.15	5.66	5.90
H_2O.....	.57	.52	.49	.37	.30	.77	.40
TiO_2.....	.19	.....	.....	.09	.07	.....	.....
P_2O_5.....	.88	.....	.....	.13	.....	.....	.03
Cl.....	.....	.....	.....	.....	.....	.....	.....
F.....	.05	.....	.....	.01	.....	.....	.....
S.....	.14	.....	.....	.02	.....	.....	.....
MnO.....	.35	.09	.08	.21	tr.	.07	.10
BaO.....	.10	.....	.....	.06	.13	.....	.05
	100.19	100.23	100.10	100.69	99.73	100.18	100.22
Magnetite..	6.57	2.73	4.32	4.29	1.58	1.85	1.86

1 Basic syenite from near Raquette falls. E. W. Morley, analyst.

2 Augite syenite, road from Tupper Lake to Wawbeek. E. W. Morley, analyst.

3 Augite syenite, 3½ miles north of Tupper Lake Junction. E. W. Morley, analyst.

4 Red, quartz, hornblende syenite from north boundary of Litchfield park. E. W. Morley, analyst.

5 Augite syenite, Loon Lake, Franklin county. E. W. Morley, analyst.

6 Augite syenite, Little Falls, Herkimer co. E. W. Morley, analyst.

7 Quartz, augite syenite, 2½ miles south of Willis pond, Franklin county. E. W. Morley, analyst.

With the exception of No. 6 (syenite from Little Falls) the rocks represented are from the interior of the Adirondacks, away from the mine localities.

2 **Sedimentary group.** The association of magnetites with distinctly Grenville types of gneisses and schists is characteristic for the St Lawrence county occurrences, as well as for some in southern

Essex county, notably around Crown Point. Compared with the preceding group the most striking peculiarity of these magnetites is the constant association of pyrite which brings the sulfur content up to very considerable amounts, a feature that has been a serious handicap to their development in the past. The pyrite may possibly be traceable to original organic matter in the sandstones, limestones and shales from which the present rocks have probably been derived. The widespread occurrence of graphite in the same rocks is noticeable.

At Benson Mines, St Lawrence county, the ore body consists of an impregnated zone in a quartzose banded gneiss. The gneiss contains sillimanite and scapolite in addition to the feldspar, while the dark minerals include hornblende, biotite and augite. Garnet and pyrite are prominent. The walls in places are cut by a later hornblende granite.

The Clifton mines, north of Benson, and those on Vrooman ridge, near Fine, are found within a black hornblende schist with interbedded layers of impure crystalline limestone. The latter occurs next to the ore in one of the openings at Clifton.

At Jayville the same sedimentary series is in evidence, though here the ore bodies and walls (hornblende-biotite schist) have been invaded by a great granite mass which has broken up what was apparently a continuous bed into numerous lenses and shoots that seem to give out in depth after passing the limits of the schist. Curiously enough, the ore contains little pyrite. There is evidence of recrystallization of the magnetite, and contact action has caused the formation of great masses of hornblende and abundant titanite.

The several mines near Crown Point have opened on bands of pyritous magnetite which are inclosed by a black hornblende gneiss that has been correlated with the Grenville of this section. The gneiss has been intruded by granite and in some places the latter lies close to the ore. The ore bodies are parallel in all respects to the St Lawrence county deposits.

Origin of the magnetites

The origin of these ore bodies has been variously interpreted by geologists. The problem is an obscure one, involving as it does accumulations of ores in rocks which are among the most ancient known on the earth's surface and which in many cases have undergone great vicissitudes from compression and metamorphism. So

long as the nature of the rocks themselves remained doubtful, the problem might be viewed obviously from several standpoints.

The sedimentary theory of origin has been held in most favor perhaps by geologists. The condition precedent to its application is that the inclosing formations are themselves of sedimentary derivation. Different modifications of the general theory are possible: the deposits may be considered to have been laid down in the form of magnetite, in which case they represent original surface concentrations such as the magnetite sands that are found along the shores of lakes and streams; they may have been originally limonite or carbonate ores deposited from solution and subsequently changed under the influence of the metamorphism that has affected the wall rocks. The apparent conformity between the deposits and the foliation of the gneisses, their lineal development and persistence for long distances on the strike are supporting arguments for the sedimentary theory.

In a previous paper on the Mineville deposits,[1] Professor Kemp gave the first detailed account of the geological surroundings of the magnetites. As a result of his investigations, he was led to question the applicability of the sedimentary theory to the ores of that district. The existence of igneous masses in the vicinity and the evidences of their agency in the formation of many of the accompanying minerals were remarked and adduced in support of the view that the ores have been introduced by processes connected with the intrusion of those rocks, more particularly the gabbro of Barton hill. In the present contribution it has been possible to clear up some doubtful points relating to the geology of the district, with the result that a more immediate source of the iron minerals in the augite syenite is indicated.

For the occurrences in the midst of intrusive rocks, which have been found to be the prevailing type in the eastern Adirondacks, there would seem to be no escape from the conclusion that the ores have formed by igneous action. They are related to the wall rocks just as the titaniferous ores are related to the gabbros and anorthosites.

The processes which led to the accumulation of these deposits may have varied in some degree in the different localities. Magmatic differentiation has been, no doubt, a prominent factor in the early stages of their formation and perhaps is competent to explain the whole course of their development. Yet there is reason for believing that other agencies were active in producing the final

[1] Geology of the Magnetites near Port Henry, N. Y. Am. Inst. Min. Eng. Trans. v. 27. 1898.

results. Of these the influence of highly heated vapors and waters arising from the igneous mass has been most important. The occurrence of fluorite, apatite, hornblende etc., intercrystallized with the magnetite, is suggestive in that line, as well as the frequent accompaniments of pegmatite and vein quartz. This agency would be specially active in the final stages of cooling and consolidation of the wall rocks. In some cases it may have been the determinative factor in bringing the iron minerals into their present position. The ore bodies thus formed would be comparable in a way to pegmatite dikes.

Some authorities are inclined to doubt the efficacy of magmatic differentiation as applied to the formation of ore bodies in rocks of acid composition. There seems to be no valid reason for thus limiting it to the gabbros and anorthosites of the Adirondacks. The relative acidity of the rocks appears to the writer not so important as the relation between the iron and lime-magnesia percentages. With a large excess of iron over the amounts required for combination with the latter to form augite, hornblende and biotite, the segregation of iron minerals might well be expected. This is exactly the condition presented by the wall rocks of the ores. From the analyses that have been given on a preceding page, it will be seen that even the more acid of the intrusives carry relatively high percentages of free iron. The amounts of magnetite calculated for the rocks, all of which are from localities outside of the mine districts, run from 1.58 to 6.57 per cent. Higher percentages would be found, undoubtedly, in specimens taken from the actual wall rocks. With 5 or 6 per cent of magnetite a concentration of 10 to 1 would produce the leaner ores that are mined in this region.

The granites and syenites of the Adirondack iron ore districts constitute a group that has some elements of relationship with the gabbros and anorthosites. This is manifested by a similarity in important features of chemical composition and by the existence of transition types. The ores they inclose differ mainly in the titanium content. In the silicious rocks, the titanium has combined with lime and silica to form titanite which has been held mainly in the body of the rock mass. With the basic magmas, the silica has been entirely taken up by the feldspathic and ferromagnesian constituents and the titanium consequently united with the iron and has been concentrated with it in the ore bodies. The ores in the acid rocks commonly contain a fraction of one per cent or so of titanium in the form of titanite.

The pyritic ores that are found in the Grenville gneisses constitute of course a distinct class. They may be ascribed possibly

to some process of sedimentation as outlined above, but it would appear to the writer more reasonable to regard them as introductions subsequent to the formation of the wall rocks. They apparently antedate the period of deformation during which the surrounding rocks were subjected to their final compression and folding.

As a rule the deposits are more irregular than would be expected in stratified bodies. They have no well defined bounds, but shade off into the country rock. It is seldom that the character of the hanging and foot shows any marked change that can be taken for original variations in the sedimentation. The thickness of some of the deposits is excessive when compared with known examples of bedded iron ores; the Benson body, for example, measures over 200 feet across the strike and the country rock is mineralized over much greater width.

Though it is believed that the ores are of epigenetic or secondary derivation, there is little basis of facts to support a more precise explanation of their origin. The view that they were formed before the surrounding rocks had undergone final rearrangement appears reasonable, because they have laminated textures and follow closely the general field structures. Their introduction may thus have taken place before the rocks were metamorphosed, in which case it might have been accomplished by ordinary ground-water circulations, with limonite or carbonate replacing the shales and limestones as the first step. The presence of organic matter in the beds, indicated by their content of graphite, would exercise a reducing action favorable to the formation of magnetite rather than hematite under the ensuing metamorphic conditions.

Mining and milling in the Adirondacks

Both underground and open-cut methods are used in the Adirondack mines, the latter, however, being restricted to a few large ore bodies or those so situated as to present a considerable surface development. In general the high inclination of the bodies and their narrowness across the strike render a system of underground working the most suitable from the start. Inclined shafts or slopes following the dip of the ore have been generally adopted in preference to vertical shafts which in some instances at least would seem to offer important advantages as regards economy of operation. The deepest shafts are at Lyon Mountain, about 1500 feet measured on the incline. Horizontal drifts are extended on either side of the shaft at more or less regular intervals and the ore stoped out between them, leaving occasional pillars of ore for roof sup-

port. In the Old Bed workings at Mineville, the ore is removed in large chambers which are extended downward with the progress of operations, as the main mass of ore lies nearly vertical. The chambers are of great size, measuring 200 feet or more from roof to floor. Timbering or other artificial support is not required in the Adirondack mines, and little trouble has been experienced from caving. The workings are relatively dry, as the wall rocks are nearly impervious to water.

Concentration of the magnetites has been practised since the early days of mining in the region. As early as 1836, according to local records, a plant was in operation at Palmer hill for treating the ore by a magnetic process. The details of this installation, an interesting precursor of the modern plants, have unfortunately been lost, though it is hardly probable that the venture could have been successful. A wet gravity system of concentration was commonly used up to about 15 years ago when the magnetic process was perfected to an extent that made its introduction feasible. This process is now generally recognized to be well adapted to the Adirondack magnetites.

At present there are six concentrating plants in the region; two are installed at Mineville, two at Lyon Mountain and one each at Arnold hill and Benson Mines. Another plant is in course of erection at the Cheever mine near Port Henry. In 1906 the mills at Mineville, Lyon Mountain and Arnold hill, which were the only ones operated, crushed 729,091 long tons of ore, making 479,644 long tons of concentrates.

The system of magnetic concentration employed is practically the same at all the mines. It involves dry crushing, sizing and treatment of the product by magnetic separators of which the Ball-Norton drum type is the one commonly used.[1] The crushing is regulated as to fineness by the granularity of the ores which varies at the different mines. As a rule it is not carried to the point where the greatest saving of the magnetite would be effected, since the production of fine concentrates is not desirable from a metallurgical standpoint.

The difficulty in handling the finer grades of concentrates in the blast furnace has been something of a drawback to the success of magnetic concentration as applied to ores in which the magnetite is intimately intergrown with the gangue minerals, an association that is not uncommon in the Adirondacks. Briquetting has not

[1] For further details of the apparatus and methods used, consult the issues of the *Engineering and Mining Journal*, for June 9, and November 17, 1906, wherein are described the mills at Mineville and Lyon Mountain.

been attempted on a commercial scale, though it has been used successfully elsewhere for similar materials.

The concentrates from the Adirondack mills carry on the average 60 to 65 per cent iron. Besides raising the iron content, magnetic concentration affords a partial elimination of the phosphorus and sulfur, important advantages for some ores. In fact the treatment of the Old Bed ores at Mineville is designed particularly to reduce the phosphorus, and the concentration is rather incidental to that purpose.

The costs of mining and milling differ of course according to local conditions. With a modern plant 75 cents per ton is probably a fair average for underground mining under favorable circumstances. Quarry work has been conducted for less than half that amount at Benson Mines. Magnetic concentration costs from 25 to 40 cents per ton of material treated. For a period of ten months during 1900, the total cost of producing concentrates at Benson Mines, including mining, milling and general expense, is said to have been $2 per ton, which is equivalent to about 80 cents per ton of the crude material handled.

Statistics of ore production

The production of magnetite in the Adirondacks has amounted in all to something over 35,000,000 long tons. The total can not be stated accurately, though there is little doubt that the figure given represents a minimum. The actual production may be larger by two or three million tons. The following table gives the nearest possible approximation of the output distributed among the leading districts; it is based upon the statistics included in the reports by Smock and Putnam and in other publications and upon records of mining companies that have been obtainable. The statistics are carried down to the end of 1906. They are based on the marketable product as shipped to the furnace.

DISTRICT	LONG TONS
Mineville	25 000 000
Lyon Mountain	3 500 000
Arnold and Palmer hills	2 000 000
Hammondville	2 000 000
Saranac valley	500 000
Fort Ann	350 000
St Lawrence county	300 000
Other mines	2 000 000
Total	35 650 000

It is only within the last 25 years that statistics of the annual production have been recorded. The table below embraces all data that could be collected from published sources. The figures for the years previous to 1904 have been taken principally from the annual reviews by John Birkinbine, contained in the *Mineral Resources*, while those for 1904 and subsequent years have been compiled at the State Museum.

YEAR	LONG TONS
1879	420 341
1880	531 000
1881	637 000
1882	675 000
1883	500 004
1884	504 894
1885	379 077
1886	583 752
1887	768 852
1888	789 419
1889	779 900
1890	821 994
1901	329 467
1902	451 570
1903	451 481
1904	559 575
1905	739 736
1906	713 692

The period of maximum development in the Adirondack mines may be said to have extended from about 1860 to 1890. In the 10 years following the latter date for which no figures are available the output was comparatively small due to the depressed state of the iron markets and the expansion of the Lake Superior districts which were able to sell ore at a lower figure than was possible with the Adirondack mines. Since 1900 there has been a noticeable improvement in the conditions; the output for the past two years has been nearly as large as at any time previous and it will probably show an increase for the next few years, provided there is no marked falling off in the demand for iron ores.

MINES NEAR FORT ANN

The Potter, Podunk and Mt Hope mines are situated on the west side of Putnam mountain in Fort Ann township, Washington co. They are reached most conveniently from Fort Ann village which by the indirect wagon road is 9 miles southeast. The elevation of their outcrop according to the topographic map is about 900 feet. The total production of the three mines is reported to have been about 350,000 tons.

Potter and Podunk mines. The ore bodies outcrop near the foot of Podunk pond and but slightly above its level. They are included in a belt of schists which belong probably to the Grenville series, though no limestone was found in the vicinity. The schists, as exposed in the hanging wall at both shafts, consist of quartzose bands alternating with thinly laminated hornblendic and micaceous layers. They carry considerable amounts of pyrite. Their dip is 45° northeast. The rock on the foot-wall side is concealed for some

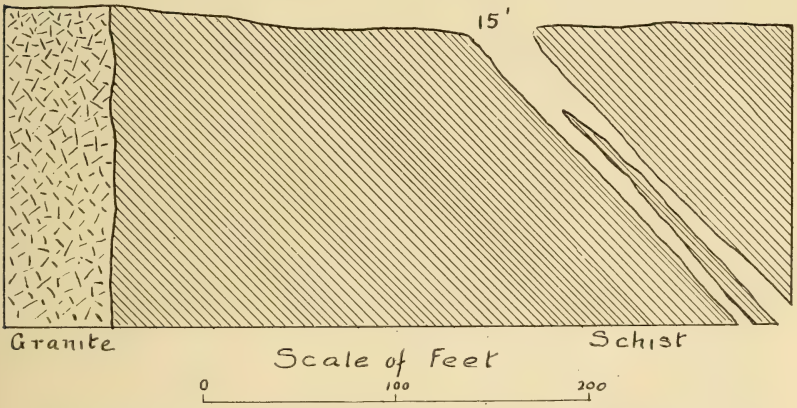


Fig. 2 Cross-section of the Potter mine, showing wall rock (Grenville schist) cut off on the south by granite

distance, but at one point midway between the two mines and 100 feet south there is an exposure of reddish gneissoid granite. This rock is found to the west in frequent outcrops and in such relation with the schists that its intrusive character is plainly indicated. It is a microcline, quartz, hornblende granite quite like the Hammondville type except that the texture is usually more finely granulated.

The Potter mine is 250 feet northwest of the Podunk. It was opened in 1879. A slope 100 feet long runs down the footwall at an average inclination of 32°. At the time of Putnam's report the ore had been stoped out for a distance of 175 feet southeast of the slope. His report contains a sketch of the workings from which

the section included herewith has been prepared. A notable feature shown in the section is the horse of rock which splits the ore body into two seams. The horse thickens to the northwest, reducing the ore breast proportionately, so that the limit of profitable working was soon reached in that direction. On the southeast only the hanging seam 10 to 15 feet thick has been exploited.

The Podunk mine on a parallel ore body is bottomed at 300 feet. There are several hundred feet of drifts extending horizontally from the slope. The ore breast is said to have averaged 8 feet. A third opening called the Baker has been made on a deposit west of the Potter mine. It has produced only a few hundred tons. The dumps at the Potter mine contain possibly 2000 tons of waste ore that evidently carried too much pyrite to be shipped to the furnace. The sulfur has been oxidized to a great extent and washed out by long weathering so that the material might now be valuable. This ore came from a zone specially rich in pyrite; most of the output was sufficiently free from this mineral to be merchantable. Chemical analyses indicate a phosphorus content that meets the Bessemer requirement. Of the following, which have been communicated by Mr S. R. Potter, No. 1 relates to a sample from the Potter mine and No. 2 to a sample from the Baker opening.

Fe_2O_3	49.00	41.30
FeO	21.98	18.47
SiO_2	23.10	35.22
TiO_2	nil	.....
S	.22	.....
P_2O_5	.014	.05
Al_2O_3	3.70	1.61
MnO	.09	.42
CaO	1.39	.45
MgO	.....	3.14
	99.494	100.66
Iron	51.46	43.30
Phosphorus	.006	.02
Manganese	.070	.32

Mt Hope mine. The ore belt continues in the direction of the strike northwest from the Potter mine and after an interval of a little more than half a mile outcrops along the ridge known as Mt Hope. According to published accounts ore was mined here 50 years ago. The last period of activity was from 1879 to 1881, when 15,000 tons or more were taken out and mostly stacked at the mine.

The workings are situated on the east, south and west sides of a north and south spur of Mt Hope. A drift has been excavated entirely through the hill on the strike of the ore, showing a thickness of 10 feet at the western entrance. It opens into a chamber 200 feet long, extended down the dip to the water level, and averaging 6 or 8 feet in hight. In another drift to the north two seams of ore 24 and 80 inches thick occur. The dip ranges from 10° to 30°. On the east side of the hill there are three open cuts which are on the same or parallel veins.

The deposit shows a tendency to form shoots and the walls are irregularly spaced with evidences in places of slight breaks. The reddish granite which has been mentioned as occuring on the foot-wall of the Potter and Podunk mines appears in force, sometimes in contact with the ore and again giving way to the schists. Bunches of black garnet are found in the latter, possibly as a result of contact action.

The ore averages leaner than the product from the Potter and Podunk mines on the eastern end of the belt. It is mixed with pegmatite, hornblende, mica and other minerals, but contains little pyrite. Most of the material in the stock pile is low grade and probably would not assay over 30 per cent iron as an average. The following analyses give the composition of the ore. In No. 1 which has been communicated to the writer by Mr S. R. Potter the iron is reported wholly as monoxid. The analysis was made by Messrs Booth, Garrett & Blair of Philadelphia. No. 2 is quoted from Maynard, the analysts being Maynard and Wendell.

	1	2
Fe_2O_3	.....	42.09
FeO	85.481	19.10
SiO_2	7.180	20.04
TiO_2	.370	.....
S	.077	.32
P_2O_5	.038	.21
Al_2O_3	3.533	7.90
MnO	tr.	.32
CaO	2.380	7.87
MgO	1.280	2.46
	100.339	100.31
Iron	61.900	44.31
Phosphorus	.017	.092
Titanium	.272	.....

A sample stated by Putnam to have been taken from the stock pile near the western entrance to the drift gave:

Iron	36.99
Phosphorus	.055
Titanium	nil

MINES NEAR CROWN POINT

In the vicinity of Crown Point on Lake Champlain and west of there toward Hammondville are a few scattered ore bodies that have received attention in the past, principally as sources of supply for the Crown Point furnace. Among them are the Vineyard, Butler, Kent, Breed and Hammond mines, besides one or two prospects. The Mt Defiance hematite mine, south of Fort Ticonderoga, may also be included among the number. The Crown Point furnace has not been operated for the last 15 years and is now dismantled.

Geologically, the magnetites of this area show striking differences from the Hammondville group which lies immediately west of Crown Point. They are associated with banded gneisses and schists that can be classed without reserve in the sedimentary or Grenville series. They have a simple tabular or lenticular form, swelling and narrowing to some extent along the strike and dip, but otherwise are little disturbed. They lie conformable to the foliation of the walls, which is plainly marked. In their mineral composition they differ from the Hammondville ores in having a high sulfur content, due to disseminated pyrite and, in most cases, a higher percentage of phosphorus as well. Their admixture with pyrite was a serious drawback to their utilization, since there were no mills for concentrating the ores in this section.

The Grenville rocks which occur near the ores are mostly hornblende and biotite quartzose gneisses with occasional intercalations of thin bedded schists. They are conspicuously foliated and variable in their composition from layer to layer. Their color is generally gray, from light to dark shades, sometimes almost black. Pyrite is a common ingredient, while graphite is not wanting. Crystalline limestone has a very limited distribution, apparently, in this area, though abundant farther west. The only occurrence observed near the mines is at the old eupyrchroite locality on the north side of Breeds hill, just south of Crown Point village, and here it is confined to a thin bed of coarsely crystalline graphitic material associated with a dense quartzite.

The Grenville has been broken up into patches and larger irregular areas by granite which has invaded the series from below. The granite is more or less gneissoid, but yet has a quite massive appearance in contrast with the sedimentary gneisses. It consists mainly of microcline and quartz, with biotite and magnetite as the principal dark minerals. It is of pinkish color. The granite frequently cuts across the stratification of the sediments and sends off dikes and stringers which penetrate the latter in all directions. It is very likely a part of the same mass described as being intrusive in the Grenville around Hammondville to which it is very similar in its characters.

Vineyard and Butler mines. These mines are located on the same deposit. They lie in the narrow valley between Buck mountain and the next ridge to the west known as Dibble mountain, just over the border of Crown Point in Ticonderoga township. Their outcrop is 2 miles distant from and 500 feet above Lake Champlain.

The Vineyard mine was last worked by the Lake Champlain Ore & Transportation Co., during the years 1887 and 1888, but it had been under operation 40 years before. Some of the ore was used at the Crown Point furnace. The deposit can be traced along the outcrop for 100 rods or more following the highway that leads to Crown Point Center. It is inclosed by a laminated black hornblendic gneiss. The strike for most of the distance is a little west of north, but on the south end it bends around and becomes east of north. The main workings are on the southern portion and consist of open cuts and shallow pits sunk on the dip which is westerly at an angle of 40° or more as measured near the surface. The principal pit has recently been pumped out. It is less than 100 feet deep and shows 5 feet of ore at the surface which widens to nearly 15 feet at the bottom.

The ore is a fairly rich, coarse magnetite. It contains pyrite in variable amount, more abundant toward the walls than in the central part. The following analysis by J. B. Britton is quoted from Maynard who states that it was made from a sample after rejecting the most sulfury portion.

Iron	51.34
Silica	21.07
Sulfur	1.17
Phosphorus	.36
Water	.24

The Butler mine is located on the northern continuation of the Vineyard. It consists of surface workings of only a few feet depth. The body seems too narrow in this direction.

Kent mine. Thin bands of magnetite appear in the gneiss on the southern slope of Dibble mountain. Three places were found where ore has been taken out in small quantity. The deposits are thin and have been worked only superficially. The production could not have been more than a few hundred tons.

Breed and Hammond mines. These are situated on top of Breeds hill, 1½ miles south of Crown Point. Together with a third opening lying on the east shoulder of the hill they form an interrupted band of ore that extends across the hill in a northeasterly direction. There is a slight offset in the lines of outcrop of the ore bodies which is suggestive of faulting. The walls in both mines consist of dark, hornblende-biotite gneiss carrying pyrite, but the granite appears in close proximity and seems to have cut it off on all sides, limiting the former to a narrow belt.

The Breed mine is opened by an inclined shaft sunk at an angle of 45°. There is a drift 20 feet long at the bottom. The deposit is said to have afforded a breast 8 feet thick. The ore contains biotite and hornblende in considerable quantity, but portions are quite rich. It is highly sulfurous.

The Hammond mine which lies up the hill and to the east of the Breed is opened by a vertical shaft of no great depth. The outcrop shows about 5 feet of ore, similar to that just described.

Howe mine. A little exploration has been done on a deposit situated 6 miles northwest of Crown Point. The pit is 5 feet wide and has been excavated on a band of ore which runs northwest up the face of a prominent ridge. A line of magnetic attraction is traceable to the south of the pit, while higher up on the ridge a 2 foot band of rich magnetite outcrops with the same strike. The inclosing rock is hornblende gneiss. Pyrite is present in the ore.

Blye mine. This is a prospect 2 miles north of Crown Point Center on the southern face of Coot hill. The test pit shows a fairly rich magnetite, but the development work is insufficient to afford an estimate as to the size of the deposit. An area of magnetic attraction is reported on the top of the ridge, toward which the ore trends.

Mt Defiance mine. An interesting occurrence of hematite ore is found just south of Fort Ticonderoga station and west of the Delaware & Hudson Railroad tracks. Mt Defiance is the termina-

tion northward of the high ridge separating Lake George and Lake Champlain. It is made up of a greenish slightly gneissoid rock which has been described as containing microperthite, augite, hypersthene, hornblende and quartz, a composition that plainly establishes relationship with the augite syenites.[1] The mountain thus represents without doubt an igneous knob that has been intruded in the surrounding gneisses which are mainly sedimentary. The ore body occurs near the base of the mountain occupying a vertical fissure with a strike n. 70° w. The walls on either side are brecciated, and there has probably been more or less displacement though of uncertain extent. Close to the fissure the rock is mashed, altered to a greenish material which seems to be mainly chlorite, and impregnated with hematite. There is every reason for believing that the ore has been introduced by circulation of underground waters subsequent to the formation of the fissure. It is plainly not an altered magnetite band. The hematite is principally a soft amorphous variety, with occasionally some masses of specular; it is mixed with calcite and milky quartz. The deposit as seen from the surface ranges up to 5 feet wide. It has been worked through a drift which enters the hill a short distance above the base. Smock states that a pit was also sunk, but as the workings are full of water this can not now be seen. He further states that 8 feet of ore were encountered. Apparently the vein has been developed quite extensively for it is referred to by Watson[2] who says that 1500 tons had been taken out in the early operations. It was again mined in 1888 and ore shipped to Port Henry. Preparations were under way in 1905 for again reopening it, but after starting an adit at the base of the hill the work was abandoned.

HAMMONDVILLE MINE GROUP

The Hammondville mines are in the western part of Crown Point township, Essex co., 13 miles west of Crown Point village on Lake Champlain and 15 miles south of the Mineville district. They occupy a limited area that centers around the former settlement of Hammondville. Though mostly of small size they have furnished in the aggregate nearly 2,000,000 tons of ore (chiefly Bessemer) with an average of about 50 per cent iron.

[1] J. F. Kemp & D. H. Newland. Preliminary Report on the Geology of Washington, Warren and Parts of Essex and Hamilton Counties. N. Y. State Mus. Rep't 51. 1899. 2:512.

[2] History of Essex County, p. 385.

In the same vicinity are the Skiff, Long Pond and Schofield mines, situated on Skiff mountain, and the Harris mine near Paradox; they have subordinate rank as producers to the Hammondville group.

The exploitation of iron ores in the district dates back to 1824 in which year the Penfield mine was opened.[1] A forge was built in 1828 at Ironville, between Hammondville and Crown Point, for converting the ore into blooms and in 1845 a charcoal furnace was erected just north of Hammondville to smelt the product of the Hammond mine. The most active development, however, took place during the period from 1873 to 1890 under the Crown Point Iron Co. The mines were connected by a narrow gauge railroad with the lake at Crown Point, where a blast furnace was maintained in operation, while ore shipments were also made to the furnaces at Bethlehem and Scranton, Pa., and at Troy.

The mines were closed down in July 1893. In 1897, the property was purchased by the American Steel & Wire Co., and soon afterward the mining plant, buildings, railroad, etc., were dismantled. Recently the mines have been under exploration by the Oliver Iron Mining Co.

Geological sketch of the district

The country is broken by ridges and narrow stream valleys and has rugged contours. It is part of the foothill region of the Adirondacks, but lies close to the central uplift of anorthosites. As may be observed from the topographic map, which has been issued by the United States Geological Survey, the contours are very irregular and show little tendency to the usual alinement along a northeast-southwest axis so pronounced in most sections of the eastern Adirondack region. The ridges range from 1500 to 2000 feet reaching an extreme in Knob mountain slightly above the latter limit. Hammondville itself together with the mines is situated on the gently sloping surface of a ridge at about 1300 feet elevation.

The geology of the district, so far as concerns its broader features, has been mapped and described by Dr I. H. Ogilvie, in connection with the report on "Geology of the Paradox Lake Quadrangle, New York."[2] Since the publication of this report a more detailed investigation of the region surrounding the mines was

[1] W. C. Watson. The Military and Civil History of the County of Essex, New York. Albany 1869.

[2] N. Y. State Mus. Bul. 96. 1905.

undertaken by the Oliver Iron Mining Co., for the purpose of establishing a basis for exploratory operations with the diamond drill. The field work was carried on during the summer of 1906 under charge of Mr M. H. Newman, who has afforded the writer every opportunity to keep in touch with its progress and likewise to make use of the results. The district is extremely complex geologically by reason of the great variety of rock formations represented, which involve practically the whole series of Adirondack crystallines, and the intricate structural relations resulting from plication, faulting and the intrusion of igneous masses.

The formations may be divided in a general way into the Hammondville or ore-bearing gneiss, which is a quartz-plagioclase gneiss of doubtful relationships; a group of metamorphosed sediments including crystalline limestone and hornblendic and micaceous gneisses and schists, and an igneous series composed of anorthosite, gabbro, diabase, syenite and granite. This is essentially the classification proposed by Dr Ogilvie except that the Hammondville type of gneiss is considered by her to be eruptive and is mapped with the granites.

Hammondville gneiss. The rock inclosing the deposits is distinguished by a finely granular cataclastic texture and almost entire absence of dark minerals except magnetite. It has a homogeneous character for the most part, in contrast with the recognizable members of the sedimentary gneisses which vary greatly from place to place. Of the igneous rocks exposed in the district, it most closely resembles the granite, but differs in some particulars of mineral composition and in the more intense crushing effects which it exhibits.

Mineralogically it consists almost wholly of plagioclase feldspar and quartz. The ferromagnesian constituents are limited to occasional shreds of biotite and a little green hornblende, forming an inconsiderable proportion of the mass. Magnetite is fairly abundant, in many specimens richly so. Apatite, titanite and zircon are the remaining components.

The rock has uniformly a grayish color on unweathered surfaces, changing to brown in exposures, with sometimes a reddish stain from a little included pyrite. In the finely crushed phases it looks much like a feldspathic quartzite. In the percentage of silica present it corresponds to an acid granite with an indicated content of 70 per cent or more, but it differs from usual granites in the predominance of the soda feldspar, the potash varieties being practically absent. The magnesia and iron are below the average for

granitic rocks. The texture gives no clue to its original nature, being completely granulated in most specimens. The quartz particles seem to be an earlier crystallization than the feldspar, contrary to the usual order of igneous rocks.

Sedimentary crystallines. The principal members of the sedimentary or Grenville series are limestone, hornblende gneiss and mica schist. Dr Ogilvie has recorded the presence of quartzite and sillimanite gneiss in the upper part of the series, but they have no representation within the limits of the district. The sedimentary derivatives are closely associated in their field relations.

The limestone forms bands and larger belts that are followed by the stream courses. It is thoroughly crystalline and frequently contains such minerals as graphite, pyroxene, amphibole and phlogopite and other silicates that have originated from the alteration of the limestone and its impurities by metamorphic agencies.

The hornblendic and micaceous gneisses and schists though completely changed from their original condition show indubitable evidences of their sedimentary derivation. They are as a rule very quartzose, with a proportionately small amount of feldspar and varying quantities of hornblende and mica. They are conspicuously banded; beds of light and dark varieties alternate across the strike, their junctions being sharp like the planes separating different sedimentary beds. Garnet, pyrite and occasionally graphite occur as accessory minerals.

Intrusive rocks. Of the recognizable intrusives found in the Hammondville district, the anorthosite and gabbro are uniform in their geology and mineral character with the general types which constitute the central Adirondacks. They grade into each other by imperceptible stages and have no doubt originated from a common magma. The syenite may also belong to the same intrusive series, representing a more acidic development. It is made up of microperthite, hornblende and a green augite, but in some phases contains labradorite feldspar as well and shows a gradation toward the gabbro. These rocks are all later than the sedimentary formations which are invaded by them, though the relations can be determined infrequently by contact effects owing to the regional metamorphism that has taken place subsequent to their intrusion.

The granite found on Knob mountain and in small areas within the gneisses is a coarse reddish variety. It contains microcline as the principal feldspar, with some orthoclase and quartz, horn-

blende, biotite, apatite and magnetite. It has a more or less gneissoid appearance, and the feldspar which originally existed in porphyritic crystals has been considerably crushed, but the textural relations are those of a plutonic igneous rock. It is regularly jointed and weathers out into massive blocks. In the Knob mountain area there are included fragments of the sedimentary hornblende gneiss which it has invaded. The Hammondville gneiss to the west is penetrated by dikes and irregular masses of granitic material which are probably offshoots from the larger intrusions.

Pegmatite may be mentioned as of frequent occurrence in the ore-bearing gneiss. In almost all of the pits this rock seems to have been encountered during the mining operations. It forms masses of varying size and shape that blend with the country rock, and is quite often associated with the ore.

Distribution and stratigraphy of formations. The Hammondville gneiss occupies a compact area about 2½ miles long from northeast, near Dudley pond and its outlet, to southwest where it extends to within a short distance of Burnt Mill brook. Its width is about 1½ miles. On the north it is cut off by the intrusion of anorthosite and gabbro that stretches over many square miles in an unbroken mass. On the other sides it is in contact with the sedimentary series which occupies the valleys of Paradox creek on the west, Burnt Mill brook on the south and most of the broad ridge between Knob mountain and Penfield pond in a connected belt. The Skiff mountain gneiss which is of the same type lies across the valley of Burnt Mill brook and is thus completely separated from the Hammondville area. The contact between the sedimentary and ore-bearing gneisses on the north side of Skiff mountain appears to be well up on the slopes.

The main granite area in the district is found on the ridge east of Hammondville. It takes in the rounded prominences known as Knob and Little Knob mountains, forming an irregular mass or boss intruded in the sedimentary series. Whether it is in contact with the Hammondville gneiss to the west could not be definitely determined, but from field observations a belt of sedimentary gneisses would appear to intervene for most if not the entire distance on that side. Both Knob and Little Knob present almost vertical cliffs as seen from the west, suggesting a north-south fault scarp, a feature that was noted by Professor Kemp. There is no direct proof of the existence of faulting at this point, though in a rock cut of the abandoned mine railroad 2 miles north of

Knob mountain a brecciated zone occurs bearing nearly in line with the cliffs.

The syenite is exposed in force northeast of Hammondville in the vicinity of Overshot and Round ponds. It has the anorthosite on the west, the line of contact following just west of the road toward Dudley pond. A tongue of syenite extends southward from this area into the sedimentary gneisses for a distance of a mile or more.

The stratigraphic order of succession for the sedimentary rocks is stated by Dr Ogilvie to be hornblende gneiss at the base and limestone above, with the mica schist interbedded in both. The field relations do not indicate any unconformity between the different members. Concerning the relative age of the eruptives, Dr Ogilvie states that the anorthosite is probably the oldest while the granite and syenite are nearly of the same period. The gabbro was the last to be intruded. The most probable order is anorthosite, syenite, granite and gabbro.

The stratigraphic relations of the Hammondville gneiss present perhaps the most difficult problem in the geology of the district and one that is of special interest owing to its bearing upon the magnetite deposits. The question naturally involves the origin of the gneiss, whether this is to be considered a member of the sedimentary series and like the other members has received its crystalline character by metamorphism, or whether it represents an intrusive of which the original igneous features have been obscured through crushing and possibly a partial recrystallization. The evidence obtained from a study of thin sections of the gneiss is inconclusive. As has been previously stated the mineralogy differs in some respects from that of typical igneous rocks of analogous composition, though the differences are not so great that they can be regarded as decisive. Compared with the class of igneous rocks most closely allied in composition, that is the diorites, the chief points of contrast are in the proportions of quartz and ferromagnesian minerals, the former being much larger and the latter smaller than obtain usually in diorites. To substantiate these inferences chemical analyses of the gneiss are needed.

The field observations of Mr Newman and the writer lend some support to the view that the gneiss does not belong to the intrusive series, or at least is not contemporary with the other members of it. The granulation and intense crushing which the rock has undergone is not common in the same degree to the igneous types which at most show these effects in limited areas or zones where faulting

and shearing movements have occurred. The Knob mountain granite, the syenite and the gabbro are frequently gneissoid, it is true, but they preserve recognizable textural characters that leave no doubt as to their relationships. It seems likely, therefore, that the gneiss has suffered greater vicissitudes from compression and other dynamic influences than the igneous rocks due to an earlier period of formation. No apophyses or masses of the gneiss approaching dike form have been found in the adjacent sedimentary series and contact effects are wanting. On the other hand the gneiss is involved with the hornblende gneiss in a way that is difficult to explain on the theory that the former has been intruded into the latter. Alternating bands of the two rocks occur along the borders of the areas. This feature is particularly well developed south of Hammondville in Burnt Mill valley, where the bands of hornblende gneiss may be observed more frequently as the contact is approached. The regularity in width of the bands, their perfect conformity to the strike and their persistency suggest interbedding rather than inclusions caught up by an invading igneous magma. If the view that the gneiss is not an intrusive be accepted, then the rock probably belongs in the sedimentary series. The alternative that it may represent a part of the basal complex on which the latter have been laid down has little claim to attention since on this theory the same difficulties would arise in explaining the contact relations with the sediments that are met by the intrusive theory. The existence of a fundamental system of rocks underlying the limestones anyway has not been established beyond peradventure in the Adirondack region.

The structural relations of the gneiss are very obscure. Satisfactory readings of dips and strikes are not obtainable over much of the area, owing to absence of those minerals which produce foliation. That the rock has been subjected to intense plication is evidenced by the included pegmatite bands, which are folded and twisted in the most intricate manner, as well as by the structure of the ore bodies hereafter described. The observations of dips and strikes where made point to a concordant arrangement of the ore-bearing gneiss and the sedimentary rocks. The latter as a rule show strikes that follow more or less closely the outline of the area, suggesting that they wrap around and overlie the gneiss, though their inclination seems to be quite irregular. The attitude of the whole series may be the result of a compressed anticlinal fold.

If originally a sediment the ore-bearing gneiss has probably been

derived from a feldspathic sandstone or arkose. The hornblende gneiss and mica schist on the other hand, are doubtless to be referred to an argillaceous deposit, and the crystalline limestone to a calcareous one. The order of succession presented by the series is thus a normal one, such as is found in sedimentary strata which have been deposited on a gradually sinking shore line.

Description of the mines

Hammondville mines. The accompanying plan, reproduced from the original recently prepared by the Oliver Iron Mining Co., indicates the distribution of the principal deposits and to some extent their underground continuations. The mine maps of the Crown Point Iron Co. have unfortunately been destroyed and complete details regarding the workings can no longer be had. The present plan has been compiled from such records as are still available and from the results of diamond drilling; it can be relied upon no doubt as reproducing the more important features [fig. 3].

The deposits in all cases are surrounded by the plagioclase gneiss which has been called the ore-bearing formation. They show no relation to the latter in the way of gradation, but have well defined boundaries. The only noticeable change in the gneiss as the ore bodies are approached consists in an increased proportion of magnetite, which gives it a somewhat darker appearance, and the development at times of a hematite stain resulting from the oxidation of this mineral. The magnetite seldom amounts to more than 5 per cent of the whole.

In their arrangement and form the deposits are characterized by great irregularity. Over 30 different openings have been made on as many ore bodies. Whether or not they occupy a definite horizon in the gneiss scarcely admits of determination, because the foliation of the latter is so obscure that little can be learned as to the stratigraphic structure. Putnam has expressed the view that they do occur in such a relation. With due allowance, however, for folding and faulting, the existence of which has been established in the ore bodies themselves, it would be difficult to bring them all into alinement, and it is more likely that there were originally two or three parallel series of deposits, probably tabular in shape; by compression and displacement these have been folded and broken up into the large number of lenses, shoots, pockets and bands now distributed with little apparent order. The strike perhaps in the majority of cases is northeasterly, but it is sometimes nearly east and west and occasionally northwest. The dip is more

Fig. 3 Ha

Fig. 3 Hammondville. Sketch of the principal workings. From a map compiled by the Oliver Iron Mining Company

often toward the south compass points than toward the north points.

Most of the deposits proved to be small and were quickly exhausted. The few notable ones which have yielded the greater part of the output for the district include the Penfield, the adjoining West End, the Hammond, Dog Alley, North and No. 7 mines.

The Penfield mine, with the West End, in the central part of the ore belt may be ranked among the largest in the Adirondacks. It is based on a deposit whose outcrop can be traced for 1000 feet. The line of outcrop forms nearly a right angle. The body is thus divided into a somewhat longer western portion which strikes northeast and an eastern portion with a northwest strike. The latter consists of a simple tabular bed swelling and thinning to some extent and dipping 15° or more to the northeast. The Ayers pit is on the extreme eastern end, across the Hammondville

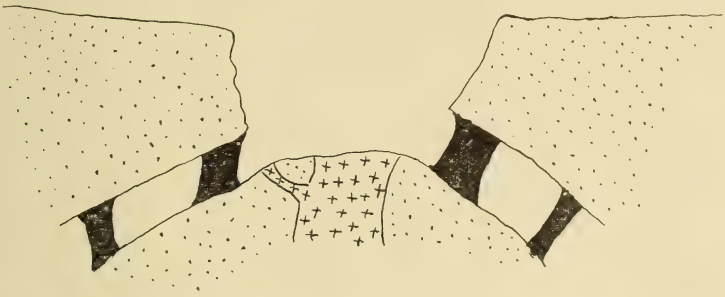


Fig. 4 Section across the Penfield pit, western portion. Pegmatite developed along axis of the fold

road. The central and western portions are more complex in form; their outcrop lies evidently on the apex of an anticlinal from which the ore runs off to the southeast and northwest. The main workings are on the northwest wing of the fold following a dip of 45°, while the ore to the southwest pinches out rapidly on the dip. The foot-wall exposed in the open cut along the axis of the fold consists of coarse pegmatite. The accompanying section [fig. 4] shows the relations in the western portion of the deposit.

The relations of the West End and Penfield ore bodies are not certain from the little information that can now be obtained regarding the workings. The former seems to be an underlying body likewise developed as an anticlinal. Smock describes it in the following words: "The West End is on the normal (southeast) dip of the Penfield ore body, and is remarkable for its irregular

walls and the slips which traverse it. The slope is about 900 feet long and vertically, 300 feet deep." Further particulars have been given by Professor Kemp. "The dip is very irregular, beginning in the west end with 45° it soon flattens to about 5° and then rolls abruptly over to 60°. The bed also drops away to right and left, as one descends, having thus a very curious roll, or dome-shaped outline. Swells of ore run into the foot, and smaller veins offset in the same direction. These small offsets are shot ore and very low in phosphorus." In the foregoing accounts no mention is made of the ore which lies to the north of the anticlinal axis as shown on the plan and have a northwesterly dip; it was exploited in connection with the southern workings. The West End deposit is more extensive than the Penfield, but it is not so thick on the average, though it is said to have given a breast 30 feet across in places.

The Hammond and No. 8 pits are to the northeast of the Penfield and higher up the ridge. They are located on the outcrop of a lens which strikes northeasterly and dips 30° southeast. The two pits are nearly connected at the surface but in depth gradually separate following the thicker portions of the lens. The latter shows a breast up to 20 feet thick in the exposure. Toward the edges it rapidly thins out and may be seen to branch off into small stringers of magnetite which gradually disappear in the gneiss. The axis of the lens when continued falls nearly in line with that of the Dog Alley mine, the shaft of which is about 600 feet from the nearest workings of the Hammond. A transverse fault is said to intervene between the two mines though they were considered to be on the same deposit.

As shown by the accompanying plan the Dog Alley is a long narrow body or shoot. It was tapped at the north by a vertical shaft which encountered the ore at 250 feet. It was one of the last to be worked. It yielded a large quantity of high-grade ore.

Mine No. 7 lies southeast of Hammondville on the edge of the belt where it falls away sharply to Burnt Mill valley. There are two slopes following a lens that dips 35° southeast. The main slope runs along the foot-wall and is stated by Smock to be nearly 1000 feet long. The ore is reported to have been 20 feet thick in places. Three diabase dikes intersect the ore body which is also faulted twice, with a displacement of 10 feet in one instance and of 11 to 22 feet in the other. Much of the waste rock on the dump shows the results of shearing with chloritization of the feldspar. The ore has been changed in part to martite and is veined by calcite, jasper and fluorite. The deposit gave out abruptly at the

Hammondville. Penfield pit; looking northeast

bottom on encountering a brecciated zone which probably marks an extensive fault. A drill hole was put down to a depth of over 1000 feet but failed to find the continuation of the ore beyond the fault line.

The North pit is on the ridge above the Penfield. It is partly an open cut, with a chamber running off to the southeast on the course of the shoot. A curious feature is the pods of ore along the southern edge which were worked through short inclines driven from the main chamber. Apparently they are squeezed portions of the larger body.

The Blacksmith mine is based on a comparatively small deposit which lies north of the eastern wing of the Penfield. The ore at the outcrop is from three to five feet thick and dips 30° northeast.

Exploration. The ore-bearing ground has been tested by the diamond drill, principally with a view to locating the extensions of the larger ore bodies. The drill holes have been mostly limited to depths not exceeding 500 or 600 feet. In the area between the West End and No. 5 workings, ore has been shown to exist in what seems to be a flat sheet at a depth of from 460 to 500 feet, and with a thickness of from 3 to 15 feet or slightly more. Its relation to the contiguous deposits can only be conjectured, but not improbably it represents an extension of the West End.

So far as has been observed the drills have not encountered any limit of the ore-bearing gneiss in depth. The cores show the rock to be quite uniform in character, the only marked variation being in the grain which at times becomes coarse owing to pegmatitization. The occurrence of red spots and streaks on the otherwise white core is considered a favorable indication of the proximity of an ore body; they are due to hematite stain.

Character of the ore. The Hammondville ore is compact, granular, or more rarely, a platy magnetite. The richest variety in which there is little admixture of foreign minerals is the so called shot ore made up of loosely cemented grains. In average material the iron content is about 50 per cent, the magnetite being associated with quartz, feldspar and hornblende. White vein quartz occurs quite abundantly in segregated masses and stringers. The percentages of phosphorus and sulfur are low. Of the following analyses, Nos. 1 and 2 have been taken from a paper on "The American Iron Trade" by James M. Swank, published in *Mineral Resources* for 1886. Nos. 3, 4 and 5 are from Maynard's paper "The Iron Ores of Lake Champlain." No. 3 is the result from an average sample from the Hammond mine; No. 4 from an average

sample from the Penfield, and No. 5 from a selected sample from the same mine. The analysts for Nos. 3 and 4 are Maynard and Wendell and for No. 5, T. M. Drown.

	1	2	3	4	5
Fe_2O_3	47.38	49.72	50.13	55.60	64.98
FeO	21.32	20.62	23.29	25.24	30.18
SiO_2	27.48	24.52	20.02	17.44	1.44
S	.02	.02	.....	tr.	.....
P_2O_5	.08	.06	.....	.05	.....
Al_2O_3	1.97	2.62	4.22	1.09	2.46
MnO	.....	.....	.38	.31	.17
CaO	.36	.68	1.28	.53	1.07
MgO	.10	.21	.85	.12	.....
	98.71	98.45	100.17	100.38	100.30
Iron	49.74	50.84	53.16	58.53	68.96
Phosphorus	.035	.026	.....	.022	.....

The incomplete analyses below are from Putnam's report. No. 1 relates to a sample of a pile of 7000 tons from No. 8 pit, No. 2 to a sample from a pile of 3000 tons representing the general shipping products from the mines exclusive of No. 8 pit, and No. 3 is based on a sample of the concentrates made at Ironville which were used in the forges at that place.

	1	2	3
Iron	50.73	49.09	63.30
Phosphorus	.090	.029	.030
Titanium	Present	Present	Present

The production of the Hammondville group is partly a matter of estimate, since there are no records relating to the early period of activity. In the paper by Swank, quoted above, is included a table showing the approximate output of Lake Champlain mines from the beginning down to the year 1885, in which Hammondville is credited with a total of 1,500,000 tons. This does not seem excessive as Smock reports the production for the period of 13 years previous to 1889 as 1,041,015 tons, evidently based on actual records. From the figures quoted in the volumes of *Mineral Resources*, it is gathered that the production subsequent to 1885

amounted to over 400,000 tons so that the entire product may be stated in round numbers at 2,000,000 tons.

Skiff mine. This mine, opened by the Horicon Iron Co. and later worked by the Lake Champlain Ore & Transportation Co., is near the east end of Skiff mountain 2½ miles southeast of Hammondville. It is about 500 feet above the valley of Burnt Mill brook. The deposit at the surface ranges from 3 to 6 feet wide thinning at either end. The strike is n. 70° e. and the dip is 80° south. Most of the ore has evidently been taken from the open pit, which is about 300 feet long; on the west side a shaft has been sunk, but its depth is not known. The ore averages fairly rich, probably about 50 per cent iron. Quartz is the most common ingredient of the magnetite. The wall rock resembles that surrounding the Hammondville deposits, but is more silicious and rather coarser in texture.

The analysis below is quoted from Maynard's paper. (Maynard and Wendell, analysts)

Fe_2O_3	47.59
FeO	21.41
SiO_2	20.65
S	.86
P_2O_5	.18
Al_2O_3	4.09
MnO	.27
CaO	4.06
MgO	1.08
	100.19
Iron	49.96
Phosphorus	.079
Manganese	.21

Long Pond mine. This is nearly opposite the Skiff mine on a parallel deposit which outcrops along the southern slopes of the ridge. It is entered from the surface by a short adit driven at a point 100 feet below the outcrop. The ore is gathered into parallel seams separated by the wall rock and dipping together at an angle of 60° south. The two principal seams are each about 18 inches thick. A second adit was run below the first to tap the deposit at

greater depth. A partial analysis by J. B. Britton is given in Maynard's paper.

Iron	64.76
Sulfur	.06
Phosphorus	.16

Schofield mine. Ore was mined here between the years 1828 and 1845 and used in the forges at Schroon. The openings extend for several hundred feet along Skiff mountain near the base, trending about northwest and southeast. Apparently the excavations do not reach much over 100 feet in depth. The ore is rich, but does not average above 3 feet in thickness. A large quantity of waste rock has been taken out in working the deposit. The following analysis by J. B. Britton is reported by Maynard:

Iron	62.36
Insoluble silicious matter	7.23
Sulfur	nil
Phosphorus	.02

EDUCATION DEPARTME
JOHN M. CLARK
STATE GEOLOGI

BULLETIN 119, PLATE 2

PARTS OF PORT HENRY AND ELIZABETHTOWN QUADRANGLES

MAP OF PORT HENRY AND VICINITY

The location of the mines is indicated by numbers which are referred to in the text

THE MINEVILLE–PORT HENRY MINE GROUP

BY

JAMES F. KEMP

Location and distribution of the ore bodies. The largest and most productive mines in New York at present are situated at Mineville, 6 miles northwest of Port Henry on Lake Champlain. Port Henry, the shipping point and the location of a blast furnace, is the town most widely associated with the industry in the minds of people in general, but the most important ore bodies really are at the above mentioned distance from it. In former years a very productive deposit was the basis of extensive operations at the Cheever mine, 2 miles north of Port Henry and near the shore of the lake. It is now being reopened with a view to magnetic concentration, but none the less the great center of ore production is at Mineville. There are two companies actively engaged at the latter place, Witherbee, Sherman & Co. Incorporated; and the Port Henry Iron Ore Co. The total output of the former is estimated at 15,000,000 tons, and, if to this is added the total shipments of the latter, the entire yield of the ore bodies up to date can not be less than 25,000,000 tons. There is no sign of exhaustion, and thus the amount of iron originally present in these deposits makes them rank well up among the great ore bodies of the world.

Besides the Cheever and the Mineville mines, there are several other smaller openings in the same general area. Almost within the limits of Port Henry itself is the Lee mine, a bed of somewhat sulfurous ore, now long idle. On the west side of the ridge separating Mineville from Lake Champlain and just at its foot is a series of openings locally called the Pilfershire pits, also long idle. Again just north of Port Henry, along the lake shore, according to the report of E. Emmons on the Second District [p. 236, 1842] there is a body of ore opened in his time as the Crag Harbor bed. Three or four miles southwest from Port Henry is another pit, now abandoned but opened up first by Butler and Gillette and continued under the name of the Essex Mining Co.

All these localities are marked upon the accompanying map [pl. 2], which is taken from the Port Henry and Elizabethtown topographic sheets, issued by the United States Geological Survey, the scale being 1 mile to the inch. Under the general name of the Mineville group are included a number of openings which

stretch along from Mineville for nearly 2 miles to the north, even crossing the line of the town of Moriah into Elizabethtown.

History. The first of the ore bodies to be discovered was the one which is now called the Cheever, but which when Professor Emmons was preparing his report, 1836–42, was known as the Walton or Old Crown Point vein [*see* Emmons's Report on the Second District, p. 237]. Nevertheless the name Cheever appears in Professor Beck's report on the Mineralogy of New York [p. 15]. The Cheever had been worked for 50 years when Professor Emmons visited it, and this would place its opening at 1785–90. The ore beds at Mineville were known in 1835–40, but the largest of them, as now revealed in the "21" mine (so named from the number of the old land lot) was first opened in 1846.[1] It is evident that the early mining industry was prompted by the call for ore for the small blast furnaces which still remain in states of indifferent preservation. Plate 3 is from a photograph of the old Colburn furnace which was built in 1848, and which still stands about a mile west of Moriah Center. Another one is represented by a pile of collapsed masonry, at Fletcherville, also called "Seventy five" a mile and a half north of Mineville. At Port Henry there was a furnace at Cedar Point, even in Professor Emmons's time, and this is the site of the large plant now in full blast. Twenty years ago there were two other blast furnaces called the Bay State, and situated just west of the steamboat dock. The abundant slag along the shore at this point came from them, but they have since been torn down.

The old bloomeries or forges were located where there was a water power sufficient to run the blast and the trip hammer. But for 25 years or so they have been extinct. In their day they consumed an appreciable fraction of the output of those mines which were low in phosphorus and sulfur. The ore was hauled many miles to them. By 1890, except perhaps at Standish, in Clinton county they had practically gone to the scrap pile.

Topography. Lake Champlain stands at an altitude of almost exactly 100 feet above tide. Over extended areas its bottom is well below sea level, and in its deepest parts is more than 250 feet lower than the surface of the ocean. Its western or New York shore is marked by a series of spurs of the Adirondacks which come down to the lake with a northeast trend, and either ending abruptly at the water's edge or projecting into the lake itself,

[1] *See* Eng. & Min. Jour. May 26, 1906.

Plate 3

Colburn furnace, a charcoal stack built in 1848, about 1 mile west of Moriah Center, near Mineville

contain between them reentrant bays or valleys of much gentler upward gradient. At the mouth of one of these valleys, yet at the summit of a somewhat steep terrace, is the village of Port Henry on the 200 foot contour. To the westward beyond the terrace the surface rises again quite steeply to the 500 foot contour and higher. The gentlest gradient is south of the village along the valley of McKenzie brook, a line utilized by the Lake Champlain & Moriah Railroad, which brings the ore to the docks. The general valley is abruptly closed on the south by Bulwagga mountain, a steep fault block which fronts Lake Champlain at an altitude of 1100 feet; while on the north, Bald Peak at 2055 and its southern spurs with declining hights for 3 miles, stand between the hinterland and the lake. In a general way behind this ridge and forming a broad and upward sloping valley lies the heavily drift-covered district containing Mineville, which with its mines is situated at the foot of the inclosing hills at the north. While a few ledges project above the general mantle of sand and boulders within the broad valley, yet there are 2 or 3 square miles without exposures of any kind, and the largest ore bodies themselves must have been at the outset covered by at least 15 or 20 feet of drift.

If from the summit of some neighboring mountain the observer endeavors to eliminate in his imagination the cover of drift and restore the old bed-rock topography, the valley becomes one of presumably gentle outlines, broken at the foot of many of the elevations by steep and somewhat precipitous ledges. The latter have been in part, no doubt, freshened up by the erosion of the great ice sheet, but they are believed to have been primarily caused by faulting. The broad and open character of the valley is due to the relatively easy erosion of the rock formations lying beneath, since enough exposures can be identified to lead to the conclusion that they were once and probably still are in large part Precambric or Grenville limestones and their associated sediments, whereas the hills are in most though not all cases the harder gneisses which are believed to belong to intrusive masses of rock.

These general topographic relations are brought out upon the accompanying map [pl. 2]. From it we see that Mineville is on the 1200–1360 contours, while the largest mines open on the 1300. This makes it necessary for the railway to climb 1200 feet in its 6 miles of track, and since, in the nature of the case, this rise is not evenly distributed, the engineering problem presented is one of some difficulty. Heavy engines adapted to mountain railways are necessary, but as the heaviest traffic is downward, the grades

chiefly militate against the return of empty cars and the haulage of supplies for the mines.

Geology. As affecting the ore bodies, two geological series are of chief importance, but there are at least two others of eruptive rocks which also concern them. Later than all and having little to do with the ores, but mentioned so as to complete the local geology, there are the Paleozoic sediments. The accompanying columnar statement presents all the formations from the latest above, to the oldest beneath.

Champlain clays
Glacial drift
Paleozoics { *Utica slate*
Trenton limestone
Chazy limestone
Beekmantown limestone
Potsdam sandstone
Diabase dikes
Gabbros, dark, basic and more or less gneissoid. In the mining localities of uncertain relation to the syenites
Augite syenites and related types more or less gneissoid
Anorthosites more or less gneissoid
The Grenville series of metamorphosed sediments, limestones, quartzites, hornblende schists and rusty schistose gneisses

Champlain clays. The clays appear along the lake shore and are practically limited to a zone a hundred feet more or less above it. They have no bearing upon the iron industry.

Glacial drift. Under this term is embraced the morainal materials, sands and gravels, which beginning higher up from the lake than the Champlain clays mantle all the surfaces. Even the highest peaks are not free from boulders and the rounded cobbles of the hard resistant Potsdam quartzite are everywhere throughout the area. Sometimes the drift is water sorted but in the cases which especially affect the mines in the vicinity of Mineville it consists of heavy boulders and sand. In sinking the Harmony shafts quite 200 feet of this overlying burden were penetrated and in a neighboring bore hole, 248 feet, before bed rock was reached. These depths were encountered on the side of the present valley and above the stream bottom. Under these circumstances ore bodies can only be located by means of a magnetic survey, and this method is carried out by the companies with magnetometers

of Swedish type. Explorations with the diamond drill then follow.

From Mineville southward through Moriah Center, Moriah (locally called "The Corners") and still farther, the mantle of drift extends with comparatively few exposures of the bed rock. Just east of Moriah Center, Mill brook has cut into it fully 100 feet without reaching the rock bottom. Presumably the expiring glacial activity filled the valley and the movement was probably from the northeast since such scratches as remain in the general region run n. 50°–60° e. The boulders seldom attain the gigantic size sometimes shown farther within the mountains but individuals up to 6 or 8 feet are not uncommon.

Paleozoic sediments. These strata are practically limited to the lake shore in the region under consideration. The Potsdam projects up the valley of McKenzie brook for perhaps half a mile from the water, but ceases long before it is concerned with any mines. No further mention is therefore made of any of them.

Diabase dikes. These interesting narrow bodies of dark basaltic rock are widespread and of no small scientific interest. Throughout the Adirondacks they appear not uncommonly in the mines, and usually occupy a fault line by which the ore is thrown varying distances up to 30 or 40 feet. They strike in two principal directions, a northeast set, embracing about three quarters of the known instances and an east and west set, including almost all the rest. In only one or two instances have they been observed with a northwest strike. These directions correspond with the chief structural breaks, and undoubtedly in seeking a path to the upper world the dikes have merely followed the lines of least resistance.

At Mineville, one, with an east and west strike is known in the Joker working; two or three, with a northeast strike cut the Harmony bed; one appears in the Miller pit, which is probably continuous with one of those in the Harmony bed, and another was reported from the Old Bed workings in former years. The rocks are all badly decomposed and not in good condition for careful determination. It is necessary to exercise care lest the darkened and chloritized breccias along faults be mistaken for them.

In the Cheever mine a number of dikes were met in former years and have been figured by B. T. Putnam.[1] The strike is not recorded and may be judged only from the fact that the dikes

[1] Report on the Mining Industries of the United States, Tenth Census, v. XV.

cross the east and west section which he gives. During all the writer's experience the mine has been full of water.

Diamond drill cores on the surface near the Lee pit indicate another dike in its northern extension and observations on the surface show it to be a large one. It can be traced for a quarter of a mile to the northeast.

In this district the dikes have not shown more than 4 or 5 feet of section in the mines. They are likely to appear at almost any moment and they may be associated with small faults, but they need never cause anxiety beyond this possibility.

Dark basic gabbros. These rocks are widespread and yet in less areal extent than the others whose description follows. They seem to appear without any pronounced structural relationship, but to have welled up as the last large product of the great igneous activity. The diabase dikes are so much smaller that they are not considered to be of the same order of magnitude. The gabbros are dark green or black in color and have, when closely examined, a faint pinkish cast from the quite invariable and richly disseminated small garnets, which are general throughout the mass in the form of rims around the dark silicates and iron ores. The chief component minerals are a dark green plagioclase, in rudely tabular crystals, so thickly charged with dust of pyroxene and spinel as to be at the best translucent in the slides; augite, which is black in the hand specimen and green in the slide; hypersthene of variable though sometimes large amount; brown hornblende in the same relations; and very abundant and sometimes relatively large bits of titaniferous magnetite. The feldspars on the one hand and the dark silicates and ores on the other almost never come into actual contact, but are separated by the rims of garnet referred to above, which course through the rock in faint pink bands.

The gabbros almost always show some gneissoid foliation. In extreme cases they pass into hornblende schists or amphibolites. In large part the change is probably due to dynamic shearing and dragging, but the banded alinement of the minerals may be in part attributable to original flow structures. The gabbros assume the form of intrusive sheets and irregular masses, whose outlines can seldom be worked out sharply because of lack of exposures. The railway cuts along Lake Champlain show that the intrusive mass may tongue out into the Grenville limestone with all manner of apophyses. Elsewhere single dikes are known, although they are not sharply defined anywhere within the area under discussion. In the maximum, the gabbros may cover as

much as a square mile. They are of special interest because they contain bodies of low-grade titaniferous magnetite in numerous localities. These ore deposits have received some practical attention and will be mentioned in detail later.

The gabbros and their hornblendic derivatives may be very easily confounded with the basic phases of the syenites to be next described. The two rocks look extraordinarily alike. Yet under the microscope at least, the syenitic varieties display abundant orthoclase, the gabbros plagioclase. The garnets are more abundant in the gabbros, although they do not entirely fail the syenites. The granular fracture of magnetite is more in evidence in the gabbros, but when all is said, the field observer may often be in much doubt when confronted with the dark, basic gneisses, as to which rock he is dealing with. For the present we may consider them distinct.

Augite syenites and related types, more or less gneissoid. The syenites, now that they are well understood, are proving to be one of the most important members among the rocks of the eastern Adirondacks. They were first identified in the west and north by C. H. Smyth jr, and H. P. Cushing, respectively, for although gneissoid members with the corresponding mineralogy were found in the east, they were at the outset placed with the doubtful gneisses and were not recognized as distinct eruptives. The diamond drill cores at Mineville have done much to clear up their identity, and as they afford perfectly fresh rocks in definite relationships, they are in the highest degree illuminating. For several years they have been carefully saved and recorded by Witherbee, Sherman & Co., and have been of the greatest service in the preparation of this description.

The syenite is an extremely variable magma which must have been sharply differentiated into contrasted products, which then constituted different layers in the fluid mass at the time of intrusion into the older rocks. At Mineville, diamond drill cores have in one case been available showing a continuous section of nearly 1000 feet; in another of nearly 1400 feet, and in many others of less, so that the relationships of the several layers can be carefully studied.

The typical syenite consists of microperthitic orthoclase — that is of orthoclase filled with flattened spindles of albite — of emerald green augite, which looks black in the hand specimen; of brown hornblende, and of less abundant hypersthene. Magnetite is of course present in subordinate amount, and titanite, apatite and

tiny zircons do not fail. Quartz is not entirely lacking, but in typical specimens it is a minor component. The syenite was called in the writer's earlier paper, the "Barton gneiss." A number of analyses have been made for Professor Cushing from specimens gathered in the northern Adirondacks and they uniformly run below 65 per cent SiO_2, the percentage at which quartz begins to be an important mineral in the eruptive rocks.

In the cores as well as in the hand specimens the syenite is a blotchy, black and green rock, which always has a pronounced green cast when fresh. On ledges that have been long exposed to weathering it is often decidedly rusty, especially in the basic phases. While the percentage in iron is not so very high, yet this element must be combined in one or more of the minerals in some unstable form, such that it readily oxidizes. It is often necessary to break into good sized blocks before the reasonably fresh green rock appears at the core. It has also been our experience in the field to find the syenite sometimes developing on exposure a dead white crust that resembles the anorthosites and that is deceptive. In these varieties the iron must be in small amount or else limited to some stable compound that resists decay. In fact with the variations to be next outlined and the protean appearance on weathering, it is not surprising that the syenitic rocks have so long escaped identification as such.

As a departure from the normal proportions of feldspar and dark silicate, we sometimes find the latter developing in greatly increased amount. The feldspar is far less prominent and a dark basic rock ensues which on slight acquaintance one would consider a basic gabbro or diorite. But the characteristic feldspar, as well as the normal dark silicates of the syenite, are still present, and both in the drill cores, as well as in the field, we find a quick passage from the usual variety to the basic with no eruptive contact that would indicate a separate intrusive mass or an included sediment. For these dark bands we can adduce no other reasonable conception than that the original intrusive mass was in parts more basic than elsewhere, and that if its parent magma were homogeneous, it separated, as has been so often observed in later years in large eruptive masses, into portions of contrasted composition although of common parentage. This basic syenite was not recognized as such in the writer's previous paper, but was esteemed to be a gneissoid representative of the gabbro. While it resembles this rock in the closest way, yet the drill cores now available prove its affinity with the syenites.

As contrasted with the basic members acidic varieties are also to be found most significantly in the cores but also in the natural ledges. In the acidic varieties the dark silicates retreat, it may be even to the vanishing point, while quartz enters and the rock reaches well into the mineralogy of the granites. The feldspar is most commonly microperthite as before and when mingled with abundant quartz it yields the "21 gneiss" of the writer's earlier article. Dark silicates almost entirely fail, plagioclase is rare, but magnetite is invariably present in scattered grains, which in the cores, unless care is taken, might readily be taken for a dark silicate. This rock is one of great importance in the geology of the ores since it is the common hanging wall of the Old Bed group. Although in coarseness of crystallization it does not vary in texture from the typical syenite, yet both in mineralogy and in rare associated minerals it suggests the suspicion that it has affinities with pegmatites, or that some influence such as the presence of vapors or mineralizers aided in its development from the normal syenitic magma. From this highly acidic and light colored rock the transition is abrupt to the dark basic masses of iron ore.

Another light colored phase consists of oligoclase and quartz with a few magnetites and zircons. This was specifically found above the Barton Hill group, and was described in the writer's former paper as the "Orchard gneiss." It is after all a not very different rock from the "21 gneiss." Microperthitic orthoclase implies rich soda because of its albite spindles, whereas, if the potash of the orthoclase fails and a slight increase of lime takes its place, we have the necessary components of oligoclase.

A still further variation from the normal augite syenite, is one in which the feldspar and the dark silicates, augite and hornblende, are in the usual proportions of say two thirds feldspar and one third dark silicates, and yet oligoclase takes the place of the usual microperthite. A rather acidic diorite results, but yet so involved with the syenites as to prevent one drawing any distinctions between them, as being separate intrusive masses.

In the above condensed outline of the rocks, the characteristic names of igneous types, syenite, gabbro, diorite etc., have been employed, implying that the rocks themselves are igneous. This is opposed to the older idea which is generally still held by the engineers and others engaged in the mining industry. The latter view the ores and their inclosing rocks as sediments, which conform in a pronounced degree to the sedimentary structures shown by strata in parallel arrangement and in folds and faults. The writer

does not wish to discuss at length the points for and against each of these views in this place, reserving it for the fuller space which will be afforded by a separate bulletin on the Port Henry and Elizabethtown quadrangles, now in preparation. If supporters of the sedimentary view will add to the rock names used above the word gneiss, or change the rock names into the form of adjectives, so as to have syenitic gneiss, gabbroic gneiss, dioritic gneiss, etc., thus using them as short cuts of expression for the mineralogy of the gneisses, they may still be regarded from the point of view of sediments. The full discussion requires chemical analyses, and more ample illustration. Whether we have, however, parallel metamorphosed sediments, or differentiated layers of eruptive rock, the structural features of folds and horizons are not changed and for practical purposes these are the really important considerations. The ores, which occur at Mineville as integral members of the syenitic series, are in the form of layers conformable to such banding or foliation as appears in the rocks. These layers bulge and pinch to a remarkable degree, and in the case of the Old Bed group (or Mineville group of the writer's earlier paper) extend in a practically unbroken stretch for half a mile exhibiting at the same time a very complex and puzzling fold; while in the Barton Hill group the extent is still longer but the structure is simpler. The so called Cheever bed with its extensions must be fully half a mile in length, but all the others are smaller. The bulges and pinches give a marked podlike or lenticular form so that at Mineville the ore bodies are a series of richer and thicker shoots whose long axes run in a parallel northeast and southwest direction.

The ores are granular masses of magnetite which in the Barton Hill group were prevailingly of Bessemer grade, but which in the Old Bed series are high in phosphorus from disseminated apatite. These are now run through a magnetic mill and freed of the apatite to such a degree that they are a better grade for the furnace and the apatite is salable for fertilizers. Occasionally where the apatite is relatively abundant and the ore occurs near a fault or line of crushing which has caused decomposition of the augite both in the ore and in the country rock, red hematite has been yielded and has filtered into all the little crevices and has given the ore a red color. This variety is the so called "red ore" of the cross-section. In the same way the country rock is also colored red.

In thin section the rich Old Bed ore reveals a noticeable amount of the green augite, characteristic of the syenitic wall rock. This mineral has certain optical properties that suggest a variety rich in

soda, but the inference has not yet been corroborated by analysis. The augite is, however, a much more characteristic igneous than metamorphic mineral, and militates against original sediments as the sources of the rocks and ores. The lean ores are mixed with the usual minerals of the wall rocks and among these the basic syenite is chief. Hornblende and biotite appear and bring down the percentage of iron. The Old Bed group is pretty sharply marked off against the acidic "21" gneiss, the quartz-microperthite aggregate, but scattered grains of magnetite continue out through the latter for many feet.

Anorthosites. This great group of undoubted eruptive rocks is specially represented in the western and northern portion of the area. Its typical representatives consist almost entirely of labradorite which may be very coarsely crystalline, still there are always minor amounts of augite and titaniferous magnetite and often hypersthene associated with the feldspar. The dark silicates sometimes become relatively abundant and lead to much variation in the rocks. At least one distinctive eruptive mass is known, characterized by relatively large amounts of them and later than the main anorthosites. At the headwaters of the Hudson the anorthosites contain the large bodies of titaniferous magnetite, elsewhere described in this bulletin, but they are not known to carry ores anywhere in the vicinity of Port Henry. The known titaniferous masses of this region are all in the basic gabbros.

Grenville series. Under this name it has been agreed between Canadian and American geologists to describe the undoubted metamorphosed sediments. They constitute an important belt underneath Port Henry and for 3 miles or more north. They appear also west of Moriah Corners and well over to the foothills of the bounding mountains on the west. The most easily recognized of these rocks is a coarsely crystalline white limestone, with graphite and many bunches of included silicates. There is less often a serpentinous variety or ophicalcite and with these are rusty quartz schists, mica schists, hornblende schists and thinly foliated gneisses. While there has been in the past a disposition to class with these the more massive gneisses yet it has been a growing belief as set forth above that the latter really represent the syenitic series of eruptives. The limestones and their included bands of silicates are mashed and folded in many complex and involved curves, some of which are curiously and strikingly suggestive of snakes and other organic forms. The sedimentary metamorphic rocks may possibly contain some ore bodies. The Lee bed of sul-

furous magnetite is at all events closely involved with them. Crystalline limestones occur abundantly in the 225 feet or so of rocks that overlie the Cheever ore body in the deepest part of its basin. The limestones and their associated strata appear on the surface, but the wall rock of the ore is a syenitic gneiss of the usual mineralogy. The Pilfershire ores occur in almost exactly the same relationship. The limestones are near and above but the ore is really in a syenitic gneiss. Between the Cheever and the Pilfershire there intervene nearly 2 miles of mountainous ridges of syenitic gneisses rising a thousand feet above the former, and while one may remark the similarity of position, it is rash to go further.

The Grenville series is thus closely associated with at least three of the ore bodies, but the latter are not actually in undoubted sediments.

Description of the mines

Following the map [pl. 2] the ore deposits will be briefly outlined in order from south to north.

No. 1. This pit now abandoned was opened by Butler and Gillette and continued under the name of the Essex Mining Co. The work was based upon a band of ore now represented by an excavation 40 feet long and 8 to 10 feet high, sloping at an angle of about 60° and striking approximately n. 12° w. magnetic. The dump alone reveals a rather lean ore with much hornblende and feldspar intermingled. The walls are reddish granitic gneiss. No analyses of the ore are available nor were any samples taken or notes recorded by B. T. Putnam for the Tenth Census.

No. 2. Lee mine. This opening is just in the outskirts of Port Henry and in a little hillock with abrupt north and east sides which rises from a valley covered with sand. The nearest rocks both to the east and west are the Grenville limestones and their associates, but faults quite certainly intervene between them and the mine. Its wall rock is a granitic gneiss, whose dark silicate is biotite. It is reddish in color and somewhat different both in minerals and appearance from the greenish syenitic wall rocks, elsewhere met with the ores. The ore strikes n. 20° w. and dips about 19° westward into the hill at the more northern slope, but swings around to the southeast and steepens to a 30° dip on the south. B. T. Putnam visited it in 1880, for the Tenth Census [XV: 115], and has left a plan and sections. The mine is cut off on the north by a trap dike with an east and west strike. The dike can be traced across the hills to the eastward.

The pit is now full of water and serves as a dumping ground for refuse from the neighborhood. Putnam saw the mine when active and states that 9 feet of pyritous ore was displayed in the face. In old pillars a cross-section can still be seen of lean, hornblendic ore. Putnam's analyses of samples from two lots, one of 2500 tons from the north slope, and one of 1500 from the south yielded the following. The sulfur, however, was for some reason not determined although it is the chief point of importance after the iron.

		[illegible]
Iron	45.01	44.38
Phosphorus	.047	.04

The ore is of low grade but the phosphorus is also low.

No. 3. Crag Harbor ore body. This is described by E. Emmons in the report on the Second District, page 236, as occurring in a cliff, 50 feet above the lake and half a mile below (north of) Port Henry and as being the most conveniently located of all the ore bodies in the region. It was 12 feet wide, in hornblende, and dipped 35° west. The vein extended half a mile along the lake but the ore was pyritous, tough and difficult to crush for the forge. An analysis from Dr L. C. Beck's report on the *Mineralogy of the State*, pages 15 and 37, is as follows:

FeO	24.50
Fe_2O_3	64.80
SiO_2. Al_2O_3, etc	8.70
	100.00
Iron	65.23

This old deposit is no longer worked and has almost been forgotten. It occurs where the gabbros are a marked feature in the Delaware & Hudson Railroad cuts and it may be titaniferous. Since both Dr Beck and Professor Emmons speak of its difficulty of treatment the titanium may be the reason. Little was known of titanium in their time.

No. 4. Cheever mine. This, the oldest opening in the region, is situated about 2 miles or less north of Port Henry, and at its eastern edge, outcrops rather more than a quarter of a mile from the lake shore and about 300 feet above it. The chief workings are just north of a small east and west depression, through which a little brook passes into Lake Champlain, falling over a fine ledge of Grenville limestone, one of the best exposures in the region.

There is certainly a great fault between the limestone and the eastern edge of the ore, since north along the railway the limestone gives way to greatly brecciated gneisses. Farther north again gabbro appears, but in irregular exposures mingled with hornblendic gneisses and quite difficult to understand. The ore itself, however, outcrops as a marked band or bed in green syenitic gneisses, and runs to the north for nearly a mile, with occasional pits. The Cheever at the southern end is, however, the chief one. These workings, now being revived after years of idleness, dip down steeply, at 50° or 60°, then flatten at somewhat over 200 feet vertically from the surface and run westward until cut off by a fault. Their relations are shown on the accompanying section [fig. 5] reproduced and reduced from the bulletin of the New York State Museum 14, page 346. The only point of revision lies in the fact that our recent fuller knowledge of the basic syenite gneisses, makes the occurrence of unbroken gabbro on the east doubtful. Field observations the past summer led to the con-

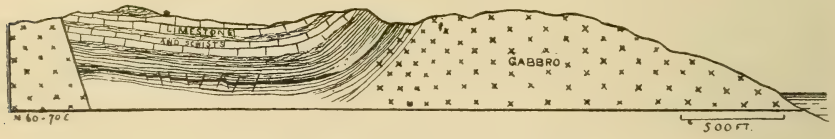


Fig. 5 Cross-section of the Cheever mine

clusion that much of the black hornblendic gneiss, formerly taken for gabbro, is basic syenite gneiss, but massive gabbro does occur mingled with it. The ore is a band in the syenitic gneiss, here quite quartzose, and about 150 feet from the undoubted Grenville. Below the ore 50 feet of similar gneiss appears before the basic rocks take its place. As the ore bed is followed north the dip appears to flatten and in an old working about half a mile from the Cheever slopes, the strike is north and south and the dip 20° w. The same wall rocks, however, appear.

Another outcrop of ore appears along the present highway a quarter of a mile north of the old Cheever engine house. It strikes northeast and dips southeast. It has limestone not over 15 feet above it and while thus apparently stratigraphically higher or nearer the limestone than the position of the western end of the Cheever, if we consider it the same bed, it suggests a synclinal basin for the ore, with a pitch of the fold to the south. There can be no doubt that a north and south fault on the west beneath a meadow cuts off both the ore and the Grenville series in this direction.

The Cheever ore resembles very closely the Old Bed variety at Mineville. It is not quite so rich in phosphorus, but is still rather high in this element. Mr Putnam for the Tenth Census [XV: 114] took six samples, four underground and two from stock piles on the surface, which showed the following percentages:

Iron	65.33	63.5	63.86	64.42	64.77	63.08
Phosphorus.	0.643	0.603	0.689	0.452	0.673	0.573

Titanic acid was found in five of the six, but its amount is very small. The ore is rich and as shown by the analyses, it is of quite remarkable uniformity. Recently [1907] a small magnetic mill has been built and concentration of the leaner unused ore is to be attempted, accompanied by a reduction of the phosphorus.

Nos. 5 and 6. These two pits are called the Pilfershire. They lie at the western foot of the ridge which intervenes between Moriah Center and the lake. Not far above them is the Grenville with its limestones, and the relations are extraordinarily like those at Cheever. Even the gabbro appears not far to the eastward as detected by F. L. Nason, who has called the writer's attention to it.

The southern pit is a small one and of no particular importance. The northern pits consist of three larger and two smaller openings. They strike nearly north and south and dip 60° west, passing below the highway 50 feet lower down. The wall rock is the familiar green gneiss which in thin section shows plagioclase and pyroxene. The mines are now abandoned and full of water.

The close parallelism between the geological relations here displayed and those at the Cheever is worthy of emphasis. In both the ore belt strikes nearly north and south and dips at about 60° west. It is in the characteristic green gneiss of almost identical mineralogy. Just above are the Grenville limestones. Just below but after an interval of gneiss is the gabbro. Between the two stands a ridge of old syenitic gneisses, with no Grenville involved and extending 2 miles without a break. Undoubtedly faulted upward, they make a mountain summit, 500 feet above the Pilfershire and 1000 feet above the Cheever.

Nos. 7 through 11. Mineville group.[1] A general outline of the

[1] In the preparation of these notes, every possible kindness has been extended to the writer by Mr S. Norton, general manager of Witherbee, Sherman & Co., Mr S. LeFevre, chief engineer, and Mr Rogers Hunt, assistant engineer. Mr Guy C. Stoltz, engineer for the Port Henry Co., has been equally courteous and helpful in affording data and advice regarding the adjacent properties.

relations of the ore bodies at and near Mineville, may first be given. There is one group of mines based on a large faulted and folded ore body in the village of Mineville itself. It outcrops at about the 1200 and 1300 foot contours and is the basis of several distinct mines, some of which are no longer worked. A half mile to the northwest, Barton hill rises to an altitude of 1880 feet and on its eastern slope, and ranging from its 1300 contour to the 1750 is a long diagonal outcrop with many pits. The group, collectively taken, is here called the Barton hill. It is possible that this bed swings around to the east under the drift and is the basis of the two Harmony shafts, south of the Mineville groups [*see* map: fig. 6]. Yet there is still much uncertainty about this connection.

At the north end of the Barton hill group a gap of concealed and drift-covered fields intervenes with no demonstrated ores. After half a mile, ore again appears in two bands one over the other, at the openings called the Fisher hill and Burt lot, both on the 1600–1640 contours and now for 10 years or so idle.

A half mile east of Fisher hill and on the 1450 contour of another hill, is the recently revived Smith mine, whose ore body is tapped still lower down by the O'Neill shaft. Another interval ensues to the north and then after half a mile two old-time but long abandoned mines are met, called the Hall and the Sherman. The former is one of the oldest in this locality and is mentioned by Professor Emmons. Drilling has recently been in progress in exploring them, but no mining has been done for many years. Still farther north no ores are known for several miles.

Mineville group. These great ore bodies are the chief source of the local production, and they present a mass of noble proportions. Thanks to the liberal spirit and courtesy of the two companies, and to the excellent and careful records of the engineers they can be so well illustrated that with the solitary exception of the Tilly Foster mine in Putnam county, they give us the best idea of the general shape and relations of a magnetite body, yet afforded in this country. At the latter the structural relations are simpler, and the amount of ore much less. The Mineville group presents a very violent case of folding, accompanied by stretching and pinching of the crest. The ores are in a pitching fold which makes depth rapidly to the southwest, so that we have to keep the relations constantly in mind in terms of solid or three-dimensional geometry. At the north end we have further to deal with a series of faults and a very puzzling relationship, which on the basis of one bed of ore is not easy to satisfactorily clear up. In the present description, the writer's

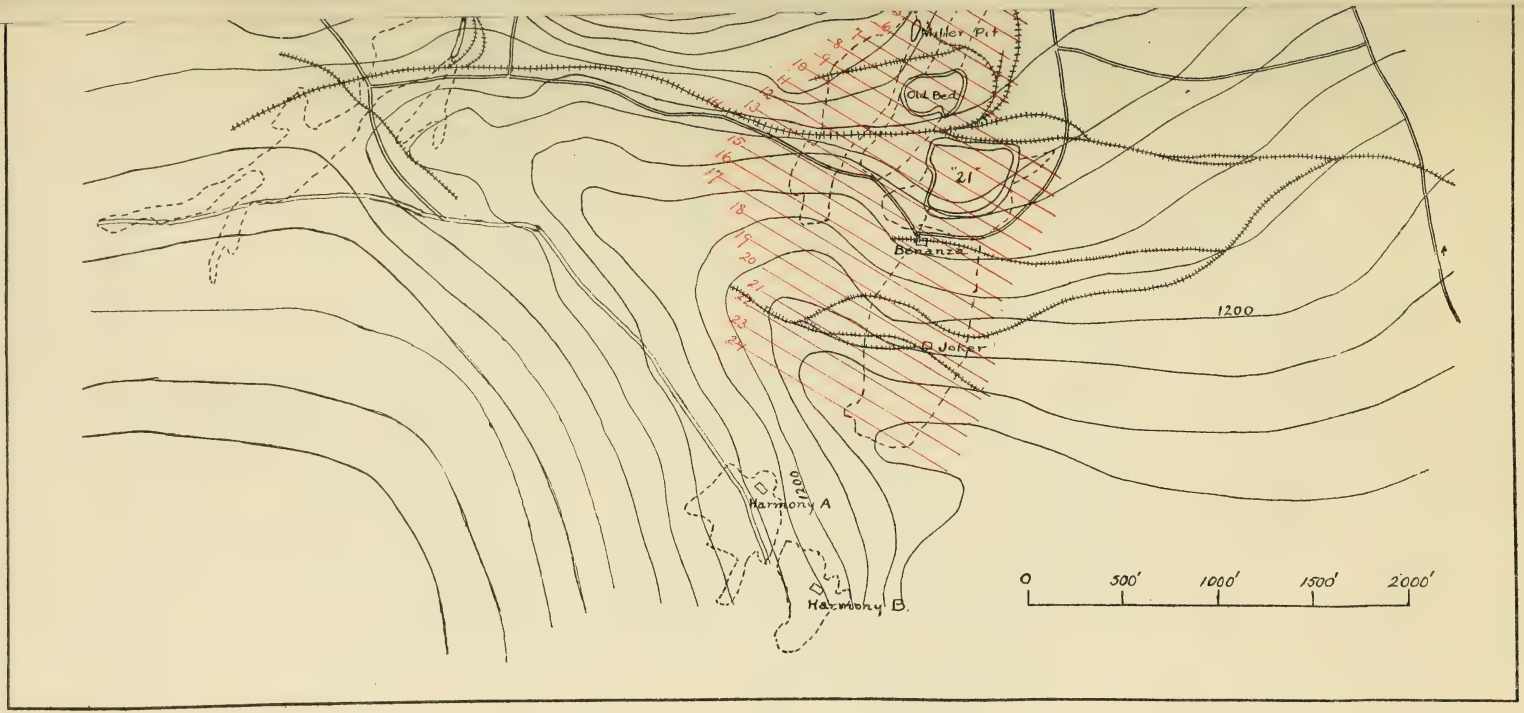
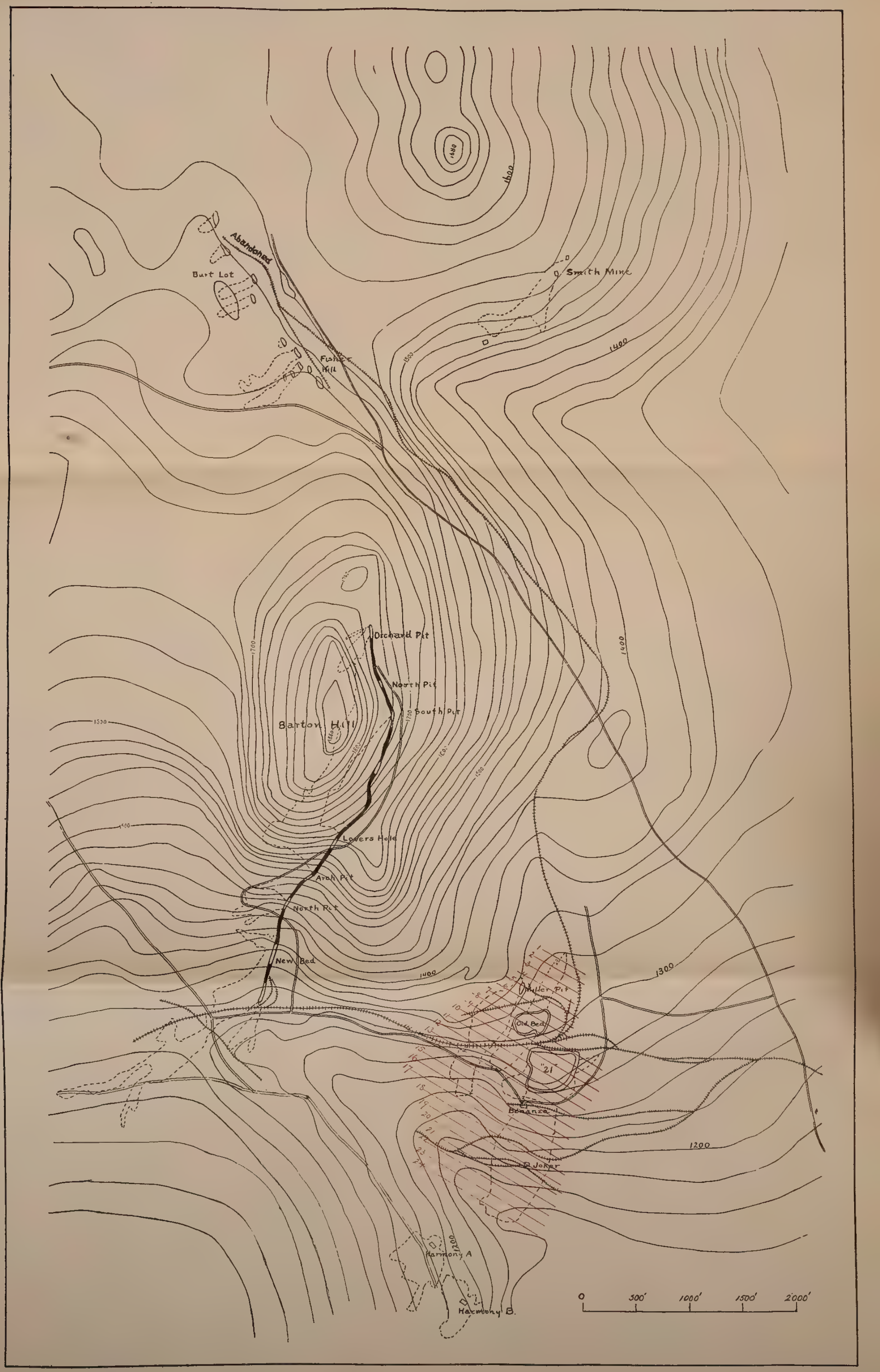


Fig. 6 Map of the vicinity of Mineville, to show the location and relations of the Old Bed, Barton Hill, Fisher Hill and Smith Mine groups. The red superimposed lines indicate the sections nos. 1-24 of figures 7-14



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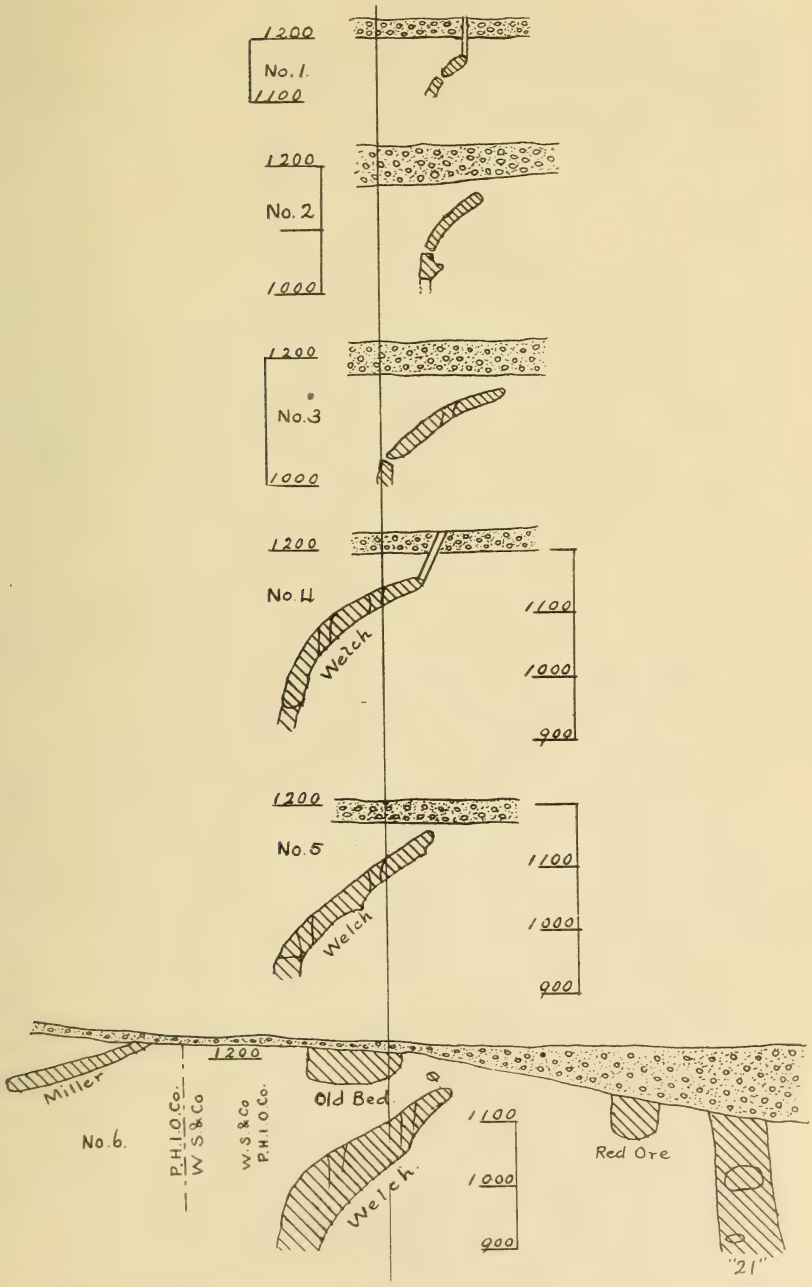


Fig. 7 Sections 1 to 6 of the Old Bed ore bodies Mineville. Sections are 100 feet apart and drawn with the same vertical and horizontal scales. *See* figure 6

paper and sections prepared in 1897 and published in the Transactions of the American Institute of Mining Engineers, volume XXVII, pages 146–204, are brought up to date and are made to include the results of 10 years of mining.

There are three principal and separate faulted parts of one great bed, viz: roughly from north to south, the Miller, the Old Bed or Mine 23 (the first discovered under the name of the Sanford pit) and the "21"-Bonanza-Joker continuous ore body, the chief source of the ore. There are several shafts for Old Bed and "21" (named from the lot) and there are large open pits as well. The axis of the fold strikes about n. 30° e., true, and, as stated pitches south. The full extent to the south has not yet been revealed. The sections here used are 24 in number, separated by intervals of 100 feet, so that they cover 2300 feet. The folded bed is broken by two main faults with strike a little more northerly than the axis of the fold, and apparently by one east and west fault under the skip way of mine "21." At least two trap dikes are known, running parallel with the main faults and probably themselves following additional small fault lines, while one other dike crosses the Joker at its southerly end in a nearly east and west direction. In the Harmony mines, the apparent prolongations of the north and south dikes are revealed. If now the reader follows the description with the diagrams beginning on the south with No. 24, the relationships can be most intelligibly stated [fig. 7–14].

Section 24 is largely inferential, but it is probably not far from the truth. The ore is a steep, vertical anticline, doubled over a fold of rock, and bulging at the lower part of the east limb. In No. 23, which is more fully based on mining experience, a great swell has developed in the eastern limb, and a tendency is shown toward a closed fold, the two limbs coming almost together in depth. In No. 22 the swell is more pronounced in the east limb, and a curious shoulder with an almost flat top has been revealed in mining. The interior core of rock shows a sympathetic development in the same way. A smaller swell or bulge is manifested in the west limb. In No. 21 the swell contracts a bit, but the bulge toward the upper left hand begins to assert itself, which is thereafter so marked a feature, and is apparently due to the stretching of a wellnigh viscous mass under irresistible compression, if indeed the rock was not still liquid from an original molten state. In No. 20 this upper left-hand bulge is much more pronounced, while the eastern shoulder is still very much in evidence. The intervening horse of rock has widened appreciably. In section 19 the upper western bulge has

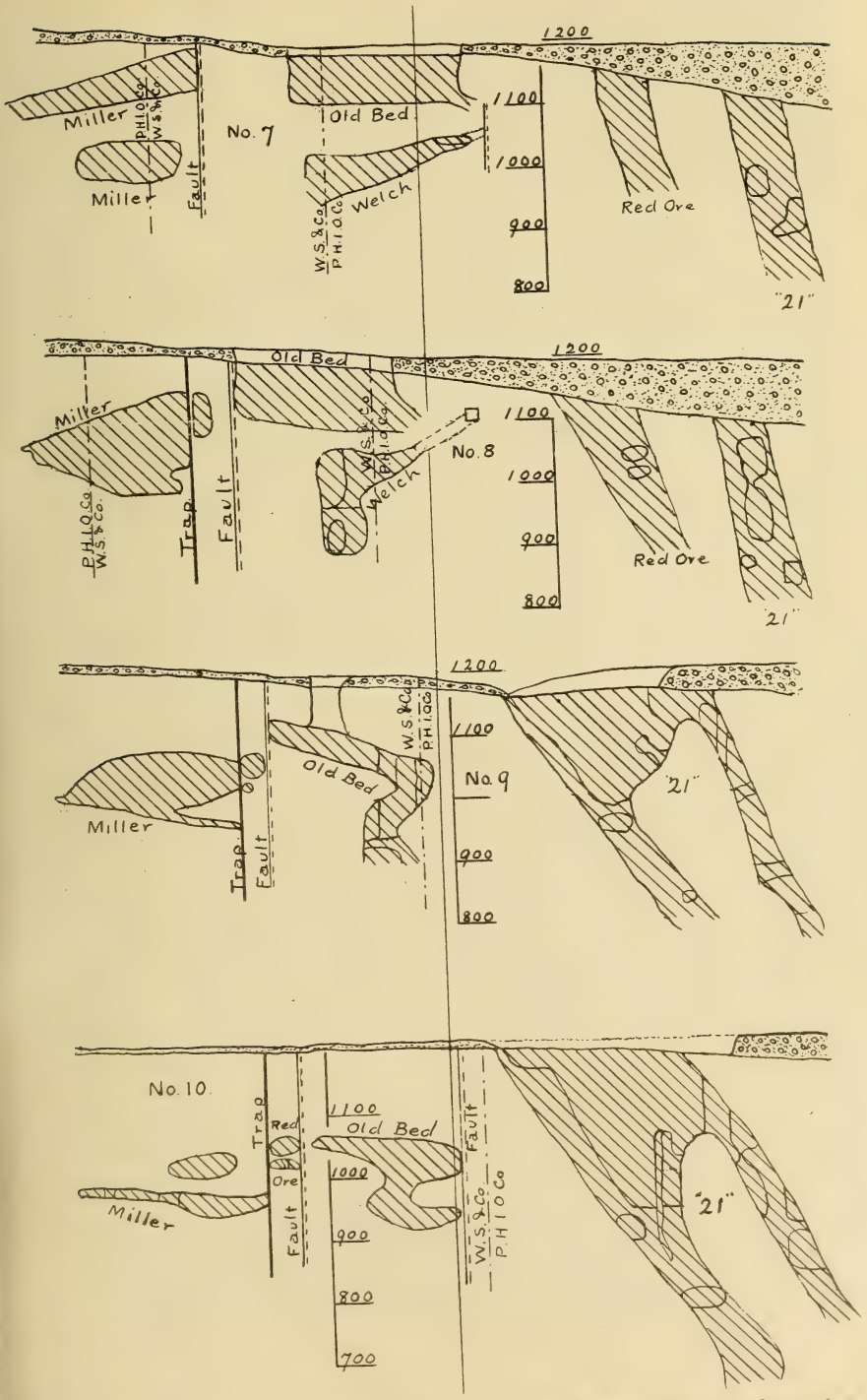


Fig. 8 Sections 7 to 10 of Old Bed ore bodies, Mineville. See figure 6

thinned somewhat, and has a very flat top, while the western shoulder has narrowed. It is very near the point where the Joker shaft first grounded in the ore. In No. 18 the upper western bulge has shrunk still more and the eastern lower shoulder has almost disappeared. Deeper mining has shown the true relations lower down on the limbs. We find them pinched together, so as to entirely circumscribe the horse of rock. In No. 18 also the sections first intersect the Miller pit as a small end of what soon becomes a large ore body. This can best be followed up by itself. In No. 17 the limbs have parted again, so far as yet indicated and the horse of rock has widened. The upper left-hand bulge has drawn in a little more. In No. 16 there is a bulge in the western limb, low down, but no very marked change in the other parts. In No. 18 we first encounter the property line and as developments have not been extensively made on the east side the data are not yet available. It is not an unreasonable expectation that the bulge in the lower right-hand limb of the earlier sections should manifest itself in depth to some extent in the as yet undeveloped portions to the north.

In No. 15 there is little change, but additional data as gained in the future will be of great interest. Between 15 and 14, a very remarkable change takes place. Apparently by a pinch and thrust from southeast to northwest a great bulge or wrinkle was rolled up on top of the anticline hitherto described, and just above its horse or core of rock. The old anticline soon pinches out but the new wrinkle bulges into a great second shoulder or roll, higher up than the one which we have hitherto followed. The latter gradually diminishes and in the end practically disappears between Nos. 12 and 11. Meantime the increasing bulge of the new wrinkle makes the noble ore body which was opened up originally in the Tefft shaft and in the great open cut of the "21" pit. The central horse of rock itself turns up to the vertical and, in the No. 13, even rolls over beyond it. All these features appear in sections 14 through 11. The upward trend or pitch of the axis of the fold now asserts itself strongly, and in Nos. 10 and 9 we see it almost reach the surface. Between 9 and 8 it emerges and thereafter the ore is in two separate limbs which run through No. 6. Beyond this point they have not been much mined in recent years, but, leaving faults out of consideration, we should expect the ore to be terminated only by the upward rise of the original outer or eastern edge of the great sheet of magnetite. This edge has been nowhere reached as yet in the deeper mining of the southern sections. It constitutes one of the

Mine 21, Mineville, N. Y. looking nearly east

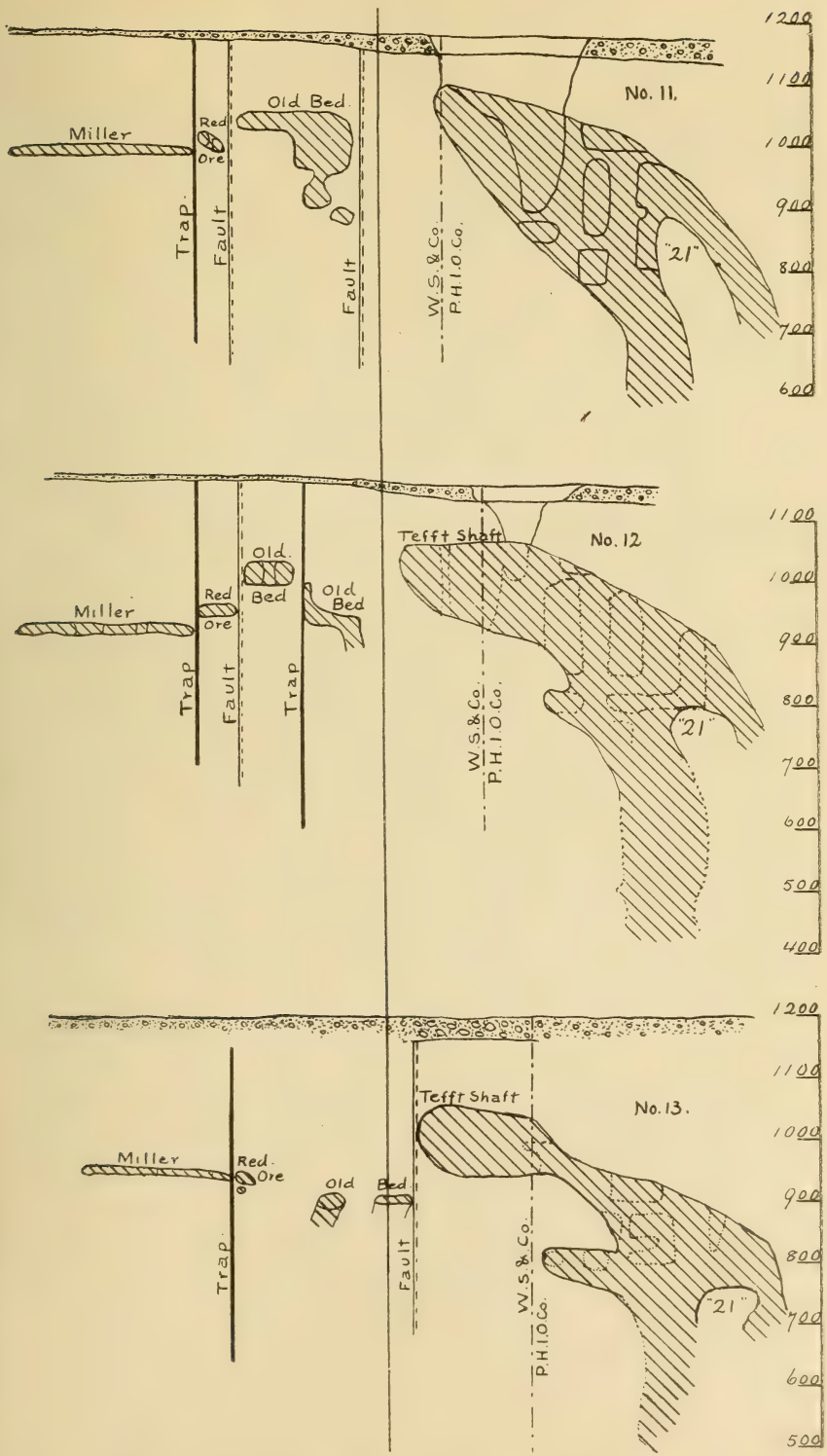


Fig. 9 Sections 11 to 13 of Old Bed ore bodies, Mineville. *See* figure 6

interesting questions for the future to develop. As to the course of the western limb, when prolonged beyond the workings as yet opened up, it is probably faulted upward in the Old Bed-Welch ore bodies. That is, it probably flattens, encounters the fault shown in sections 13 and 14, is thrown upward and constitutes the Old Bed-Welch ore body with all the convolutions of the latter. If we turn to section 10 in which Old Bed was followed up to the fault line, at about the level of 940 feet, we can see that in order to allow the western limb of "21" to flatten and come over to the fault, there must be a displacement of at least 300 feet. If the western limb of "21" rolls upward to the fault this throw will be diminished. We must not assume a purely vertical throw, since increasing experience brings home to us the conviction that almost always faults involve a diagonal shift along the fault plane.

Assuming therefore that Old Bed and Welch are the same ore body and are the faulted representative of the western limb of "21", an assumption which is corroborated by the similarity of the ores, we may follow out the curious convolutions presented by them. In sections 14 and 15 they are very indefinite and are mostly known by drill cores. The stray ore body shown in No. 15, on the center line, was revealed by a drill hole. Its identity is not known. The other one in No. 14, east of the fault and 200 feet below the Tefft shaft is also of uncertain relationships. Old Bed is first recognizable in this section, although little is accurately known about it. The ore grew small as followed many years ago and the workings were abandoned. In No. 13 Old Bed was found double, but again was not extensively opened. We know little about it. In No. 12 it develops a steplike roll of its own and is cut into two parts, by the small fault into which the trap dike has forced its way. At No. 11 the dike has pinched out and the fault was not noted. The ore is anvil-shaped and curiously pinched below. In No. 10 it is a reversed S-shaped fold and the core of rock begins to manifest itself on the west, which is of great importance in the next sections. It is similar to the ones in the Joker-Bonanza "21" fold, but dips west instead of east. It rises toward the surface and ultimately cuts off Old Bed proper, from its downward prolongation, the Welch bed, until finally beyond No. 6, Old Bed runs out into the air and is lost. Meantime the Welch limb runs along and rises, with a lima bean pod cross-section until it too goes into the air. Within the last year or two a new shaft has been sunk to tap the Welch ore on the line of section No. 1, so that we

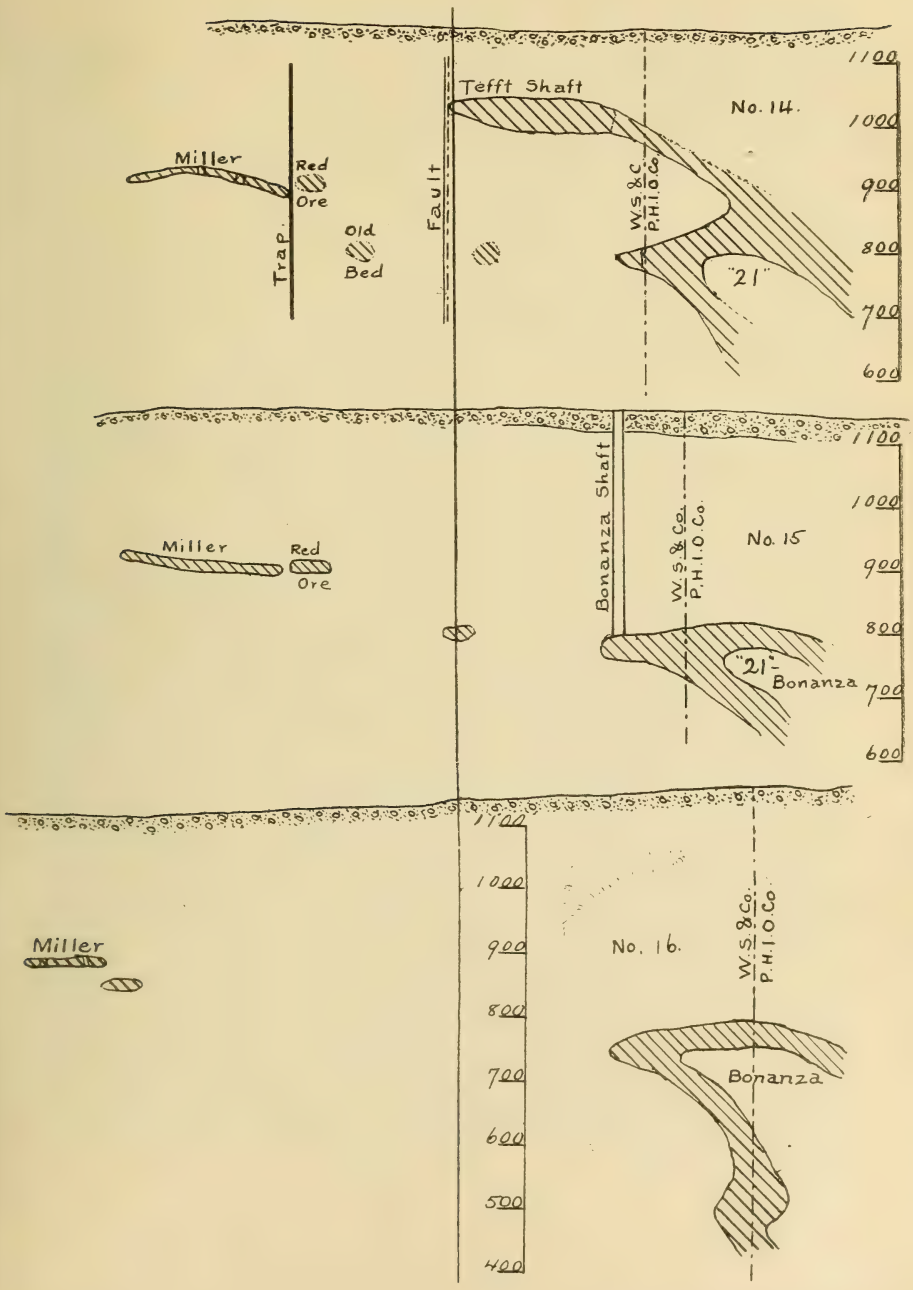


Fig. 10 Sections 14 to 16 of Old Bed ore bodies, Mineville. *See* figure 6

now know that this ore continues downward lower than was formerly shown. More recent data also show that in No. 7, rock cuts off the ore on the east, apparently before the upward curve of the ore was found and a fault is suggested.

In its western prolongation as shown in sections 8–12, Old Bed encounters faults, and an area of broken ground with one or two disconnected masses of iron-stained, apatite-bearing ore called "Red Ore." The red color is due to the crush and to the consequent alteration of some of the minerals. In the slides the color is clearly shown to be caused by red hematite infiltrations into cracks. The source of the iron oxid is without doubt decomposed pyroxene crystals.

Beyond the "Red Ore" lies the Miller pit, a very large and very interesting ore body, now practically worked out. The Miller is presumably the faulted extension of the Old Bed, which is dropped to the west, but it has in sections 7–10 a very peculiar double character. The separate parts of No. 7 coalesce in Nos. 8 and 9 and part again in No. 10, beyond which to the south the upper one, once the large one, fails entirely. We are confronted with some difficulties in following out the folds in whatever way we may try to explain them. We must consider the Miller as an expanded prolongation of Old Bed before folding; that is that the Miller was longer north and south, so as to allow for its extended pod in sections 13–18. Probably the under one of the two pods in No. 10 was connected with Old Bed and that it was doubled over on itself as shown in Nos. 7 and 8. It must either have been this or else the upper member is the prolongation and the bed was doubled under itself to account for Nos. 7 and 8. Or else the Miller is a forking pod, from a central thickened portion in Nos. 8 and 9, where the two parts coalesce. Any of these three relations is possible, but if we favor folding we can not avoid giving great emphasis to the viscosity or doughlike consistency of the rocks at the time, since in no other way could they possibly have bulged and molded themselves into these forms. So pronounced is this character that one can not well help giving serious attention to possible convolutions in a molten but ropy mass. Under the latter assumption we need infer burial in the earth at a less depth in order to make the results possible.

The following analyses illustrate the composition of the ores from the "21" pit. No. 1 was a sample of 65 carloads and No. 2 of 35 carloads from the Port Henry Co.

Plate 5

Mine 21, Mineville, N. Y. looking southwest into the Tefft shaft chamber. Mt Tom is in the background

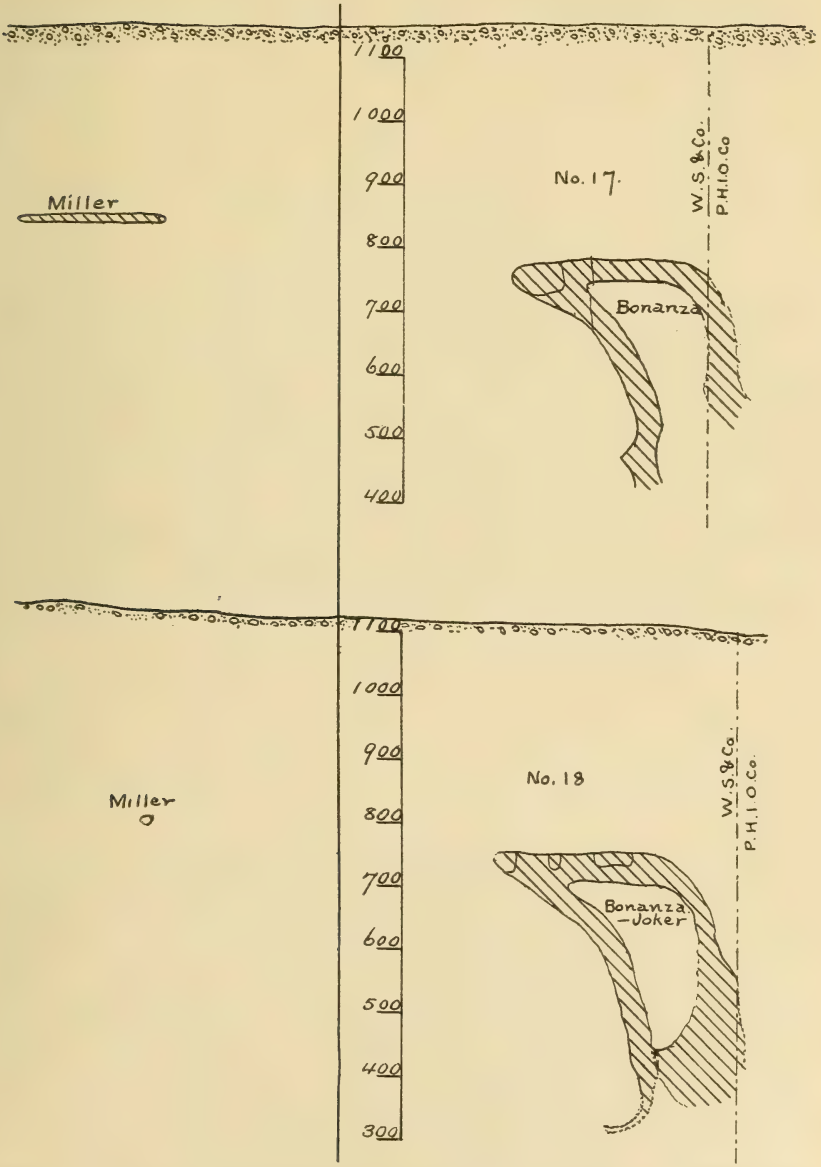


Fig. 11 Sections 17 and 18 of Old Bed ore bodies, Mineville. *See* figure 6

	1	2
Iron	60.03	60.91
Silica	4.48	4.49
Phosphorus	1.635	1.548
Sulfur	.021	.027
Titanium	.12	.03
Copper	.....	.007
Moisture	.28	.25

When the phosphorus is recast as chlorin apatite, it gives for No. 1, 9.14, and No. 2, 8.83. Calculating all the iron as magnetite, this mineral then formed in No. 1, 83 per cent of the mass; in No. 2, 84 per cent. In the sample and undetermined there was more than five per cent of CaO, and probably a little Na_2O, attributable to the green pyroxene often observed in the ore.

The analyses below, taken from the *Iron Age* of December 17, 1903, show the composition of the crude Old Bed ore and the products made by its concentration at the milling plant of Witherbee, Sherman & Co. No. 1 represents the crude ore, No. 2 the magnetic concentrates, No. 3 the first grade apatite product made by retreatment of the tailings from the first concentration, and No. 4 the second grade apatite product.

	1	2	3	4
Iron	59.59	67.34	3.55	12.14
Phosphorus	1.74	.675	12.71	8.06
Bone phosphate	.....	.....	63.55	40.30

Harmony mines. The most recent developments at Mineville are the two Harmony shafts, A and B, which were sunk 5 or 6 years ago in order to tap a bed of ore revealed by the dipping needle and the drill to the south and somewhat to the west of the Joker workings, and at a much higher horizon. The Harmony bed strikes northwest and dips southwest at a rather flat angle. It is 10 to 20 feet thick and is cut by at least 3 narrow trap dikes with a strike a few degrees east of north and a vertical dip. They fork somewhat and are not absolutely continuous. The dikes occupy small faults of 10 to 50 feet displacement and strike in a direction to suggest that they are the same with the two in the Miller pit.

The relations of the Harmony ore to the Joker on the one side and the Barton hill group on the other are interesting. Our last section of the Joker is 500 feet above Lake Champlain, while the

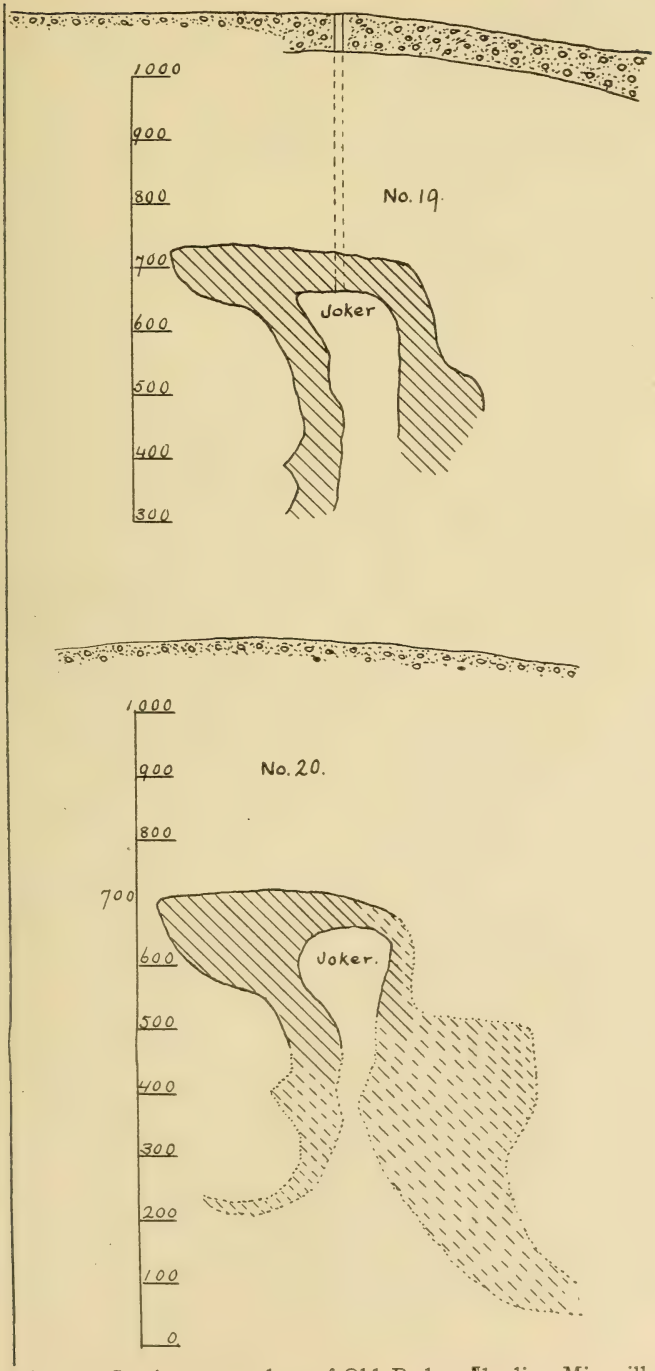


Fig. 12 Sections 19 and 20 of Old Bed ore bodies, Mineville.
See figure 6

outcrop under the drift of the Harmony bed, 400 or 500 feet away, is 450 feet higher. If the latter is the prolongation of the former there is a very great fault in the interval. On the other hand, if we attribute to the Barton hill group a swerve to the eastward under the cap of drift, there is a very strong probability of connecting up with the Harmony bed. There is unexplored ground in between with evidence of some disturbance. The composition of the Harmony ore as regards phosphorus is intermediate between the Barton hill and the Joker. It is higher than the former and lower than the latter. The percentage in iron is somewhat less than the Joker.

A third possibility must be considered, namely, that it is a totally distinct bed having no necessary connection with either of the older ones. While it is natural to seek to connect together those already known, it must be admitted that the last view can not be entirely ruled out.

Barton hill mines. These openings are distributed along a practically continuous bed whose outcrop is approximately 3500 feet long in a direction a little east of north. From the 1300 contour on the south, the outcrop rises to the 1750 on the north. From the southern end of the outcrop the underground workings follow an extended shoot of ore some 2000 feet farther on a flat dip to the southwest; and along its axis this particular branching pod must be fully half a mile long.

Taking the Barton hill bed as a whole it is characterized by swells and pinches giving the enriched and thickened shoots which have been specially followed in the mines. Their axes and therefore the workings run northeast and southwest and are therefore closely parallel with the Old Bed group, and with the Harmony beds. No doubt the relationship is due to the general system of folding which prevails in the gneissoid rocks and which has caused the rolls and attendant bulging. Upon the map of the Mineville area [fig. 6] the successive openings are given. They begin on the south with the New Bed, which is the deepest and most extensive. Then follow the North pit and the Arch pit, of moderate extent. From the Arch pit a tunnel is now being driven northwest on a slightly ascending grade so as to bring out by a gravity tram, the ore which may be tapped in the downward extension of the more northerly shoots. Already some gratifying discoveries have been made.

The next pit on the north is the Lovers Hole, the famous opening from which came the extremely rich ore and the remarkable crys-

The mills at Mineville, N. Y. looking northeast. The Joker shaft is on the right; the Bonanza shaft on the left

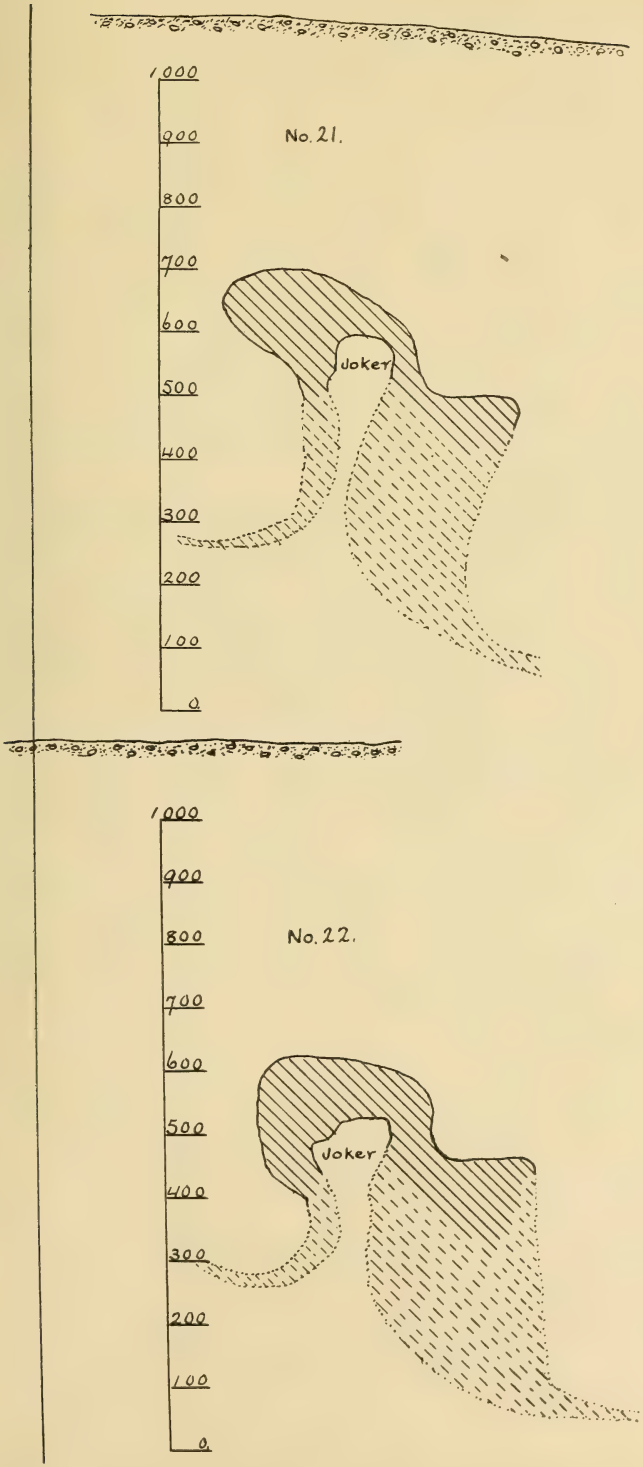


Fig. 13. Sections 21 and 22 of Old Bed ore bodies, Mineville.

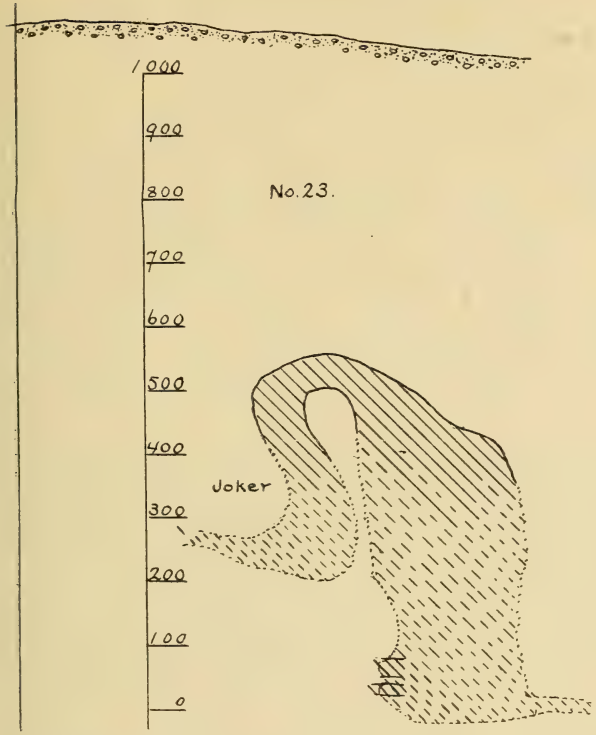
tals of magnetite, mined about 1887–88. A total of 40,000 tons from one chamber averaged 68.6 per cent and carload lots ran 72 per cent, being almost chemically pure magnetite.

Beyond the Lovers Hole is a stretch not much mined as yet, and then as the outcrop swerves with the contours to the northwest, there are three pits, the South, the North and the Orchard. The rock dumps are large at this end, indicating leaner ore. Beyond the Orchard pit, there is an interval with no mines, and mostly with concealed bed rock, for half a mile. Within this distance there is a drop of 150 feet in the altitude and then two groups of mines, now for some years unworked, are found. These are the Fisher hill mines belonging to the Port Henry Iron Ore Co., and the Burt lot, of Witherbee, Sherman & Co. The ores are rather lean but are of Bessemer grade.

The pits are distributed across a horizontal stretch of 100 feet at Fisher hill and 250 to 300 feet at the Burt lot. They dip about 25° westward, and are therefore something like 40 feet apart vertically at the former and 115 feet at the latter. There are no marked horizons of ore within these limits. At Fisher hill the workings are 600 or 700 feet down on the incline, and at the Burt lot, 300 or 400. The railroad has been pulled up for 10 years past and the mines have been allowed to fill with water.

It is quite possible that the Fisher hill and Burt lot ores are a reappearance of the Barton hill bed after a lean interval, and that they mark a northerly continuation of the latter. It is very natural to infer these belts and especially are we prone to do so in so far as the time-honored sedimentary conceptions of origin influence us. The northern pits are double to a degree not shown by the southern, and if we are influenced by the igneous views, we may not feel justified in inferring the identity without proof of the connection. The wall rocks are practically identical and the general dip and axial trend of the pods correspond.

To the east of Fisher hill and a half mile away upon the eastern slope of a different hill is another great lens or pod now known as the Smith mine, and actively worked by Witherbee, Sherman & Co., through the Cook shaft. This pod was discovered by the needle. It does not outcrop. It dips west and pitches south like the others and furnishes a non-Bessemer ore much like Old Bed, but lower in phosphorus. A vertical shaft taps the upper end of the pod and then from the foot the two skip ways fork and proceed southwest, one going for about 1000 feet. The ore varies from 20 to 40 feet thick, and at the south drops over 600 feet below its



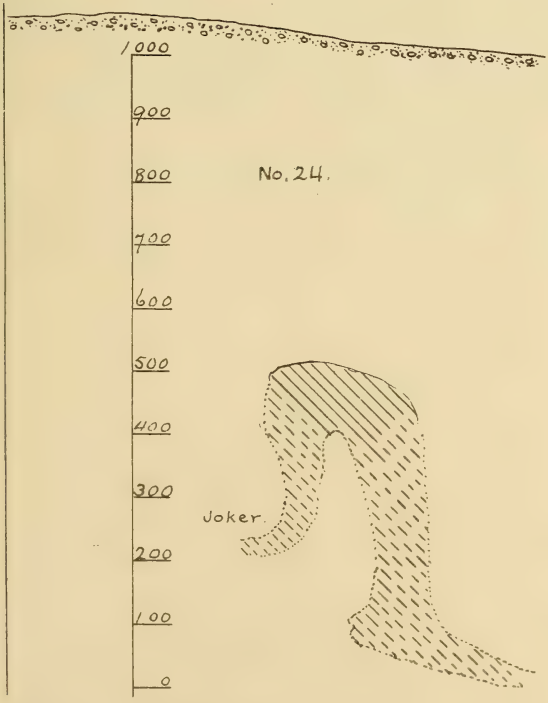


Fig. 14 Sections 23 and 24 of Old Bed ore bodies Mineville. *See* figure 6

high point on the north. At the southern end is the old O'Neill shaft, now used for pumping and in the fall of 1907 tapped by the northern workings.

Two hundred feet or so north of Cook shaft, is the Thompson, long abandoned, and beyond this an interval of some distance with no workings. Recently diamond drilling has, however, revealed ore, which may in time be worked. The hill then abruptly drops away to a small valley, on whose northern side are two old mines, the Hall and the Sherman, which were early discovered but which have long been idle. The property has passed to Witherbee, Sherman & Co., and has lately been drilled. Ore has been found in rocks the same as at Mineville, and constitutes a reserve for the future.

It is natural to consider these last mentioned beds the northern extension of the Smith mine, and it as representing the Old Bed group, farther east and lower down than the Barton hill-Fisher hill-Burt lot series; but inasmuch as the O'Neill shaft is over a mile from the last exposure of the Old Bed series with almost no outcrops between, and in rocks that are practically massive, one may quite as well regard the northern ones as totally distinct ore bodies. Again one's train of thought is necessarily influenced by the sedimentary or igneous views of origin. The axial trend of the Smith mine is parallel to the same feature in all the others to the south, and therefore shows the same great structural character, presumably due to folding whose compressive strain being at right angles to these axes, operated in a northwest, southeast direction.

Farther on to the north, no ore is known for 2 or 3 miles, and then the beds are comparatively thin and have been long abandoned.

MINERVA MINE

This is a small opening situated in the town of Minerva, about 2 miles north of the hamlet of that name. The ore body outcrops on the southern face of the long north and south ridge which rises between Minerva stream and Stony Pond brook and is known locally as Ore Bed mountain. The elevation is between 1900 and 2000 feet according to the topographic sheet. A good trail leads from the highway along Falls brook to the mine. The Burden Iron Co. operated the deposit and the ore was used at Troy. The last work was done about 1881.

The geological associations are very similar to those noted in the mines about Crown Point. The Grenville series of limestones, schists and black hornblendic gneisses outcrops in the broad valley drained by Jones brook and reaches well up the confluent valley of Minerva stream. It appears to form also much of the higher ground, though interrupted in places by a pink gneiss of granitic composition which is probably intrusive. The latter has a more massive appearance than the typical Grenville gneiss and is made up of green pyroxene crystals in a ground mass of microperthite, microcline and quartz. This gneiss was found in proximity to the ore, but not in actual contact. The immediate walls, as exposed in the pits, are formed of the darker variety, carrying hornblende and biotite as ferromagnesian minerals, and probably belonging to the sedimentary or Grenville series. Red garnet is distributed through the rock in small crystals, while pyrite occurs in considerable quantity both as individual particles and irregular aggregates.

The deposit has a northwesterly strike in conformity to the general trend of the country rocks. It has a flat dip of not more than 10° northeast, but as the surface rises sharply in that direction, the overburden soon becomes too heavy for open-cut work. There are a number of pits and trenches along the outcrop, extending altogether for a distance of 100 rods. A breast of ore 12 or 15 feet thick is exposed in the middle section. The thickness diminishes toward the ends, but it was not possible to estimate the size with accuracy owing to the partial filling in of the pits. Some drilling is said to have been done a number of years ago to test the ore body in depth; the records, however, have not been available for use in this report.

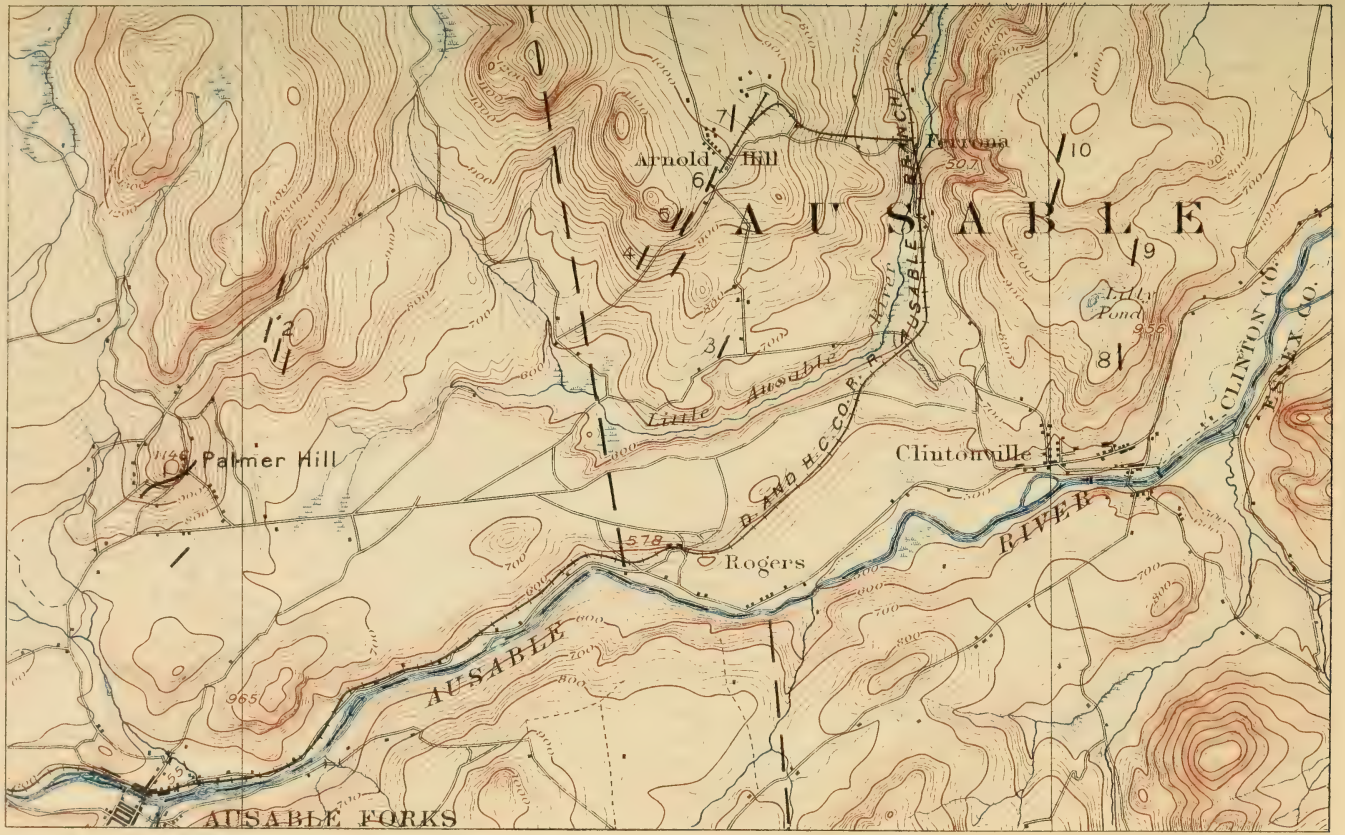
The ore is a fairly coarse, granular magnetite. Samples taken from different parts of the body indicate an iron content above

50 per cent on the average, so that it would be classed as of rich grade. The principal impurity is pyrite which seems to be concentrated in narrow bands and is not generally admixed with the magnetite. A quantity of the more sulfurous ore has been left on the surface near the openings.

ARNOLD HILL AND PALMER HILL MINE GROUP

On the southern border of Clinton county is an old mining district which includes the Arnold hill, Palmer hill and several outlying deposits. The district is easily accessible from Lake Champlain by the Ausable valley, and was one of the first in the Adirondacks to be entered by the early explorers in search of iron ores. It has furnished in the aggregate about 2,000,000 tons of furnace and concentrating ores, most of which has been used for local iron manufacture.

The mines are all found on the north side of the Ausable river within an area some 6 miles long east and west and reaching about half of that distance back from the river. Palmer hill is a knob that rises directly from the valley in the western part of the area, 2 miles north of Ausable Forks. The mines lie well up the slope and are based on an ore body that outcrops along the southern face. Northward the contours merge into a broad ridge of which Jackson hill, a slight prominence, has a few openings known as the Jackson hill mines. Still farther north, 3 miles from Palmer hill, are the Rutgers and the Dills & Lavake pits that have afforded some ore. Arnold hill occupies a central position in the area and is set off from the adjacent elevations by the trench of the Little Ausable, deep and gorgelike when it passes through the ridge to the north. The deposits are mainly near the summit, but they lie also along the southern face. On the eastern end is Cook hill with the Cook, Mace, Winter and Battie deposits. The Burt pit mentioned by Emmons has not been located; apparently it was never worked to any extent. At the foot of Palmer hill, across the Clintonville road, is an old opening which is now caved, and another called the Chalifou occurs south of Arnold hill, near the Little Ausable; both are little more than prospects. The mines are indicated on the accompanying map [pl. 7] which is reproduced from the Ausable sheet of the United States Geological Survey, with a scale of 1 mile to the inch. The mines are: 1, Palmer hill group; 2, Jackson hill group; 3, Chalifou; 4, Finch; 5, Indian; 6, Arnold; 7 Nelson Bush; 8, Winter; 9, Mace; 10, Cook mine.



PART OF AUSABLE QUADRANGLE

MAP OF ARNOLD HILL AND VICINITY

The ore bodies are indicated by heavy lines and numbered as explained in the text

General geology

The higher Adirondack ridges do not extend much beyond the Clinton county line. The Ausable in its course from the east and west branches to Lake Champlain marks the limit between the region of main uplift and the bordering foothills. South of the river the surface rises quickly to the level of the flanking ridges which is less than 1500 feet, and thence abruptly with frequent rock scarps to the interior prominences which increase in hight toward the southwest and merge into the central dominating range of Essex county. On the north side, a terraced sand plain intervenes between the river and the first ridge forming the valley wall. In the stretch from Ausable Forks to Clintonville it is from 1 to 2 miles wide but contracts below the latter place where the valley becomes very narrow. The hight of the ridge on which the mines are situated for the most part averages about 1100 feet or 500 feet above the level of the plain.

The anorthosites and associated gabbros which are so widely developed to the south do not occur in force across the Clinton county line. They compose, however, the higher prominences within a short distance of the Ausable and in the vicinity of Keeseville, east of Clintonville, even extend somewhat over the line as a narrow tongue diminishing in width toward the north. They have no bearing upon the iron ores and will not be further considered.

Gneiss series. The area surrounding the ore bodies is underlain chiefly by an acid augite gneiss, a part of the basal gneiss series (Saranac formation) which borders the northeastern Adirondacks and shows much uniformity of character throughout the area. Bands of darker gneiss and pyritous schists that can be referred to the sedimentary or Grenville series occur rarely and in limited outcrops. Of recognizable igneous rocks there are small exposures of syenite, gabbro and diabase, all intrusive in the gneiss and thus of later age.

The gneiss presents some variations from place to place, but the differences either in structure or composition are seldom so pronounced that a basis for a classification is afforded. The extremes are connected, moreover, by transition phases and are intimately associated in their field occurrence.

In its composition, feldspar, augite and quartz partake most largely. The feldspars may be microperthite, orthoclase or microcline among the alkaline varieties which are the prevailing ones or an acid plagioclase. Microperthite and orthoclase are commoner than the other varieties and their reddish color gives the predominant

tone to most specimens. Both the quartz and augite fluctuate, the proportion of the former mineral being usually about that found in a moderately silicious granite, but may shrink to very small amounts. The augite gives way at times to hornblende or biotite, a result that may be traced in part to secondary alteration.

The arrangement of the constituents may be described as gneissoid, yet it often lacks the parallelism of typical gneisses. The texture is mostly granular, such as would be produced by shearing and granulation of a massive rock with perhaps a certain amount of flowage under compression. Coarse phases in which little crushing effects are observable and grading into a pegmatite rock are not unusual in the area. They may be explained as massive aggregates which have escaped the general dynamism that has effected the granulation of most of the gneisses, or possibly they represent a recrystallization of the latter under certain favorable conditions which have obtained only in portions of the mass. That they are all intrusions from a distinct magma hardly seems possible under the circumstances owing to the frequent similarity of composition to the granular varieties as well as their textural gradation into the latter. On the whole the characters of the acid gneiss indicate its relationship to the granites.

There are few exposures of sedimentary types among the gneisses. On the south side of the Ausable, just below the confluence of the two branches at Ausable Forks, a micaceous laminated rock outcrops in a small area where the overburden of sand and soil has been washed off. It has the peculiar rusty weathered appearance common to these gneisses, due to the oxidation of contained pyrite. Some layers are extremely quartzose. The exposure has special interest from the fact that the strata are cut off on one side by syenite which breaks across in an irregular manner like an intrusive. It is the only place in the district where such evidence of the nature and relative age of the syenite has been found. The micaceous gneiss can not be traced for any distance, as the river and its deposits conceal the outcrop. The elevations on the opposite side of the river just north of Ausable Forks are mostly syenite, but there are involved masses of amphibolite and of a light colored plagioclase gneiss that probably belong to the sedimentary series. Crystalline limestone has been noted by Kemp as occurring at Trout pond, 3 miles south of Clintonville; it does not appear to be present, however, anywhere in the vicinity of the mines.

The strike of the gneisses varies considerably, but is mainly in a northerly direction. The common readings are east of north, up to

45°, with rarely one to the west of north. The dip is uniformly toward the west. In many places the foliation is too obscure to permit determinations with any certainty.

Augite syenite. This rock occupies two distinct areas at least within the district. The one near Ausable Forks already mentioned is the larger and more typical of the normal character of the syenite. As near as the limits can be drawn it forms practically a connected mass or boss, the surface of which is coextensive with that of the dome-shaped hills lying between Ausable Forks and Palmer hill. The exposure south of the Ausable is probably an offshoot from this mass. Compared with the gneiss of the region the syenite shows marked differences even in hand specimens. Its color on fresh surfaces is green, with a suggestion of gray or yellow at times, while the fracture is that of a close grained igneous rock, conditioned by its massive texture. Feldspar and magnetite are the minerals most apparent to the unaided eye. Under the microscope the former is seen to be almost entirely microperthite, while associated with it are augite, hypersthene, hornblende, quartz, zircon, apatite and rarely a light colored garnet. The feldspar is built up in stout anhedra between the interstices of which the quartz occurs in irregular grains. On the borders, especially on the east side of the mass, the rock is apt to be more quartzose and the grains attain such dimensions that they are readily distinguishable.

The second occurrence of the syenite is on Arnold hill, a few hundred feet west of the Nelson Bush mine. It is here quite different in appearance from the first, having a mottled aspect which is induced by the abundant hornblende mixed with the feldspar. Plagioclase constitutes a large proportion of the feldspar. The rock is to be regarded as a basic phase of the syenite, near the borders of the gabbro rock group.

Gabbro. The only intrusion of gabbro in the gneiss series of the district that has been found is on the south bank of the Ausable, a mile east of Ausable Forks along the Clintonville road. It is a coarse dark rock somewhat laminated but with the peculiar mottling that is so often associated with gabbroic rocks. The constituents are mostly hypersthene, hornblende and labradorite. The occurrence is doubtless to be ascribed to an outlying intrusion from the large anorthosite-gabbro area to the south.

Dikes. Diabase dikes are conspicuous features of the geology of the ore bodies. They intersect the latter in different directions, apparently without following the joint systems of the walls. Their thickness ranges up to 15 feet, the maximum reached by two dikes

on Palmer hill, but most are much thinner. They have little effect upon the ore and except where accompanied by faulting which is rare they do not materially interfere with mining operations. From the few examples that have been examined petrographically, they appear to be all ordinary diabases.

Arnold hill mines

The mines on Arnold hill comprise several separate openings located along the southern shoulder of the ridge. The ore bodies outcrop in parallel series or *en echelon* with a general trend of n. 20° e. Altogether they have been explored for a mile and a half along the strike, though of course not continuously. Beginning at the south end, the first opening, known as the Finch pit, lies at about the 850 foot contour. Next in order to the north after a short interval are several open cuts, parallel but at slightly different horizons, extending perhaps 500 feet. They have long since ceased to be productive. The Arnold or Big mine, with three ore bodies, is about 1000 feet farther north, and at about an equal distance from the Arnold is the Nelson Bush mine with its two shafts, the last to be worked. The small Chalifou pit lies to the south and east of the main group.

According to local records the earliest discovery on Arnold hill was made in 1806. Mining was begun on a small scale shortly after that date, and in 1812 the property was purchased by Arnold, Stickney & Howe who continued in possession for over 50 years. Up to the time of Emmons's report (1842) exploitation was confined to the southern deposits which he states were then being worked under lease. The mines have been intermittently active during the last half century. The most recent undertaking, the Arnold Mining Co., reopened the Nelson Bush mine, working it for a period of three years. A mill of 200 tons daily capacity was erected at Arnold Station (Ferrona on the map) and new mining equipment installed. The company ceased operations in the summer of 1906.

Geological relations. The deposits outcrop as rather thin bands intercalated in the gneiss parallel to its foliation. Their dip is toward the west and steep generally 70° or a little more. Their shape which is tabular has been modified by compression, producing undulations and pinches both along the strike and dip; on the north end the irregularities seem to be more pronounced than elsewhere and the lenticular form is the characteristic one.

The deposits have been subjected to faulting on a small scale. The direction of movement is across the strike, with the result that

the lines of outcrop are shifted laterally. In the heading of the south shaft of the Nelson Bush mine a fault of this kind was observed. Its throw could not be determined but it is probably small. Other examples which have been noted by Emmons occur in the old workings on the southern section, where the outcropping ore is offset by slight displacements that have taken place obliquely to the dip. The maximum offset found on the surface is about 15 feet. In this case a thin dike has been intruded along the fault plane [fig. 15].

The wall rock is mainly the augite variety of acid gneiss already described. Along the contact with the ore it has been considerably altered, with the development of chlorite and biotite as resultant products from the augite, while it also contains much clear quartz of secondary infiltration. A black hornblende gneiss is encoun-

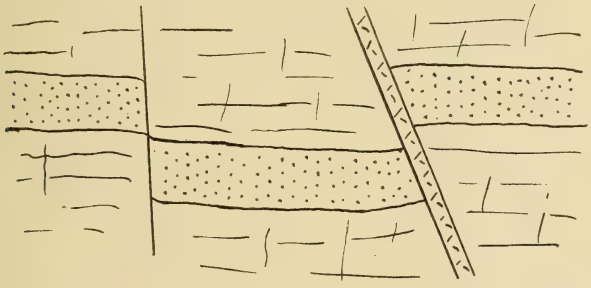


Fig. 15 Faulting of the ore bodies as seen on the surface near the Indian pit. A diabase dike has been intruded along the fault plane at the right.

tered on the walls of the Nelson Bush mine, and may represent an included band of the sedimentary gneisses to which it corresponds in composition.

Nelson Bush mine. This mine is the most northerly of the Arnold hill workings. It consists of two shafts about 600 feet apart driven on the course of two lenses which have nearly the same horizontal axis. Underground the shafts run off as inclines, the northern starting at an angle of 60° and flattening gradually to 30° and the southern at an angle varying from 42° to 35°. They are intended to follow as nearly as possible the pitch of the lenses which is about 40° north. The north shaft is down some 900 feet on the incline. The lens of ore as seen in the workings is 25 feet thick in its maximum development and averages perhaps 18 feet. In the south shaft the lens ranges from 10 to 15 feet across the walls. The two shafts are not connected underground.

The ore is coarsely granular as a rule and contains too much

foreign matter to be suitable for the furnace without undergoing some form of selection or concentration. In the recent operations the product has been milled and separated magnetically. Pegmatite and quartz are the principal foreign ingredients. Small calcite veins with a deep purple fluorite also occur. In the rich ore apatite is quite abundant. The results obtained by milling operations show that a little less than two tons of crude ore are required for one of concentrates. By the method of magnetic separation some loss is entailed by the fact that the magnetite has been oxidized in part to martite, which has the chemical composition of hematite and is very weakly magnetic. The analyses given below communicated by the Arnold Mining Co., were made from samples of rich ore (1) and the admixed lean material (2). Owing to the failure to determine the alkalis present, they are not complete, but the discrepancy is important only in the case of the lean ore which contains feldspar. The small percentages of copper and nickel are, so far as known, unusual to Adirondack magnetites. These elements are probably combined with sulfur; pyrite and pyrrhotite suggest themselves as the most likely combinations in which they may occur.

	1	2
Fe_2O_3	57.85	20.30
FeO	27.50	10.15
SiO_2	7.62	50.82
TiO_2	.39	.33
S	.038	.044
P_2O_5	.618	.43
Al_2O_3	1.68	8.32
MnO	.15	.20
CaO	2.48	2.26
MgO	1.26	1.53
Cu	.006	.....
Ni	.072	.....
	99.664	94.384
Iron	61.90	23.00
Phosphorus	.269	.188
Manganese	.116	.155
Titanium	.24	.198

Arnold mine. This has been the largest producer of all and for many years supplied the entire output. The deepest workings are about 800 feet. The loss of the main shaft by caving, 10 or

North shaft. Arnold hill

12 years ago, put a stop to underground operations and it has not since been reopened. It is said that the ore bodies narrowed appreciably near the bottom, indicating that they are probably lenticular like the Nelson Bush deposits.

In the reports of Putnam and Smock the mine is described with some detail. Three parallel bodies occur, called the black, the blue and the gray veins. They are separated by gneiss with an interval of 40 feet or less between adjacent walls. The strike is n. 35° e. and the dip 70° at the surface flattening to 55° at 325 feet depth. Smock states that the bodies run off as shoots underground pitching at an angle of 40° along the strike. The first ore body on the foot-wall side is the gray vein which varies from 3 to

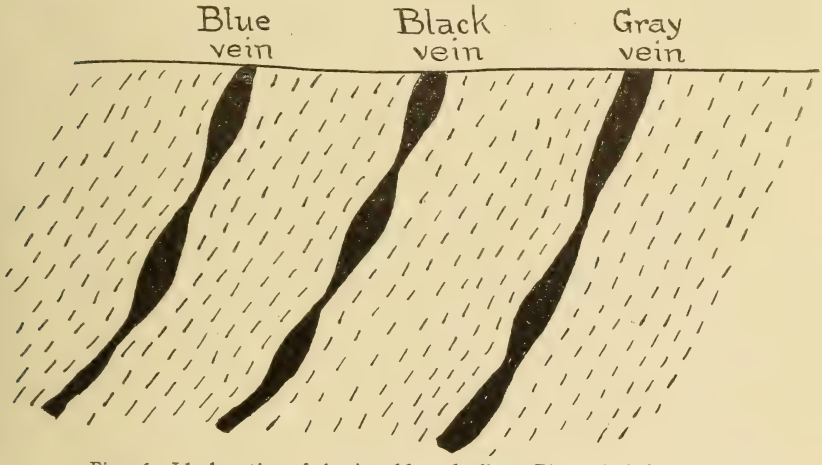


Fig. 16 Ideal section of the Arnold ore bodies. Blue vein is hematite

25 feet in thickness. The black vein in the middle is from 3 to 27 feet thick and the blue to the west about the same. There are two shafts, 500 feet apart, driven on the dip of the foot-wall vein connecting by crosscuts with the adjacent veins, and a series of levels about 700 feet long. The section included herewith [fig. 16] shows the relations of the three ore bodies.

Putnam advances the opinion that the Nelson Bush ore bodies are a continuation of the gray vein, but this can scarcely be true since the axis of the former when produced southward falls considerably to the east of the Arnold workings. No indications of a fault sufficient to account for the difference in horizon were found on the surface. It seems more probable that the two mines are located in separate horizons.

The marked variation in the character of the ore in the different veins is an interesting feature. The black vein yields a granular,

friable magnetite carrying apatite and otherwise resembling the Nelson Bush ore. The gray vein is so named because of the light-colored gangue minerals which are intermixed with the magnetite so as to lend a mottled gray appearance to the ore when seen in hand specimens. It is slightly altered. In the blue vein the ore has been changed almost completely to martite, the surface of which is steel blue in color. The change no doubt is to be explained as the effect of weathering assisted perhaps by the circulation of underground waters which have found here an easier passage, possibly along some fissured strip, than in the neighboring veins. Specimens of this ore frequently show veinings of jasper and calcite, deposited by such circulations. Analyses of the ore from the blue vein are given herewith. No. 1 has been contributed by Mr S. Le Fevre. No. 2 is quoted from the paper by Maynard on "The Iron Ores of Lake Champlain"; Maynard and Wendell analysts.

	1	2
Fe_2O_3	83.14	85.54
FeO	5.27	2.39
SiO_2	7.64	7.56
TiO_2	.26	.....
S	.035	.16
P_2O_5	.531	.43
Al_2O_3	1.72	2.71
MnO	.31	.....
CaO	.64	.98
MgO	.108	.48
Cu	.005	.....
Ni	.003	.....
	99.662	100.25
Iron	62.30	61.74
Phosphorus	.232	.188
Manganese	.24	.....
Titanium	.156	.....

Open cuts, Finch and Chalifou pits. The open-cut workings south of the Arnold mine were the sources from which ore was obtained during the early period, but they were abandoned with the discovery of the larger deposits to the north. The only information about them that has been placed on record is contained in Emmons's report. There are four parallel deposits, according to this authority, the richest being from 2 to 8 feet wide, known as the blue vein, with martite. At the time of the report, it had

Mill at Arnold hill

been worked to a depth of 260 feet and for a length of 500 feet. Regarding the other deposits, he states: "The four veins upon the Arnold hill are in proximity to each other, being separated by a few feet of rock. The width of the black vein is from 3 to 11 feet, and that of the gray veins from 2 to 8. The quality of the ore furnished respectively by each is very similar and the products of reduction nearly the same; preference, however, is given to the old blue vein." Some 800 feet west of this group there is a fifth vein which has been opened in a small way. The ore is reported to have been of poor quality.

The Finch pit south of the foregoing is probably on a continuation of the same deposits. It has been sunk through several feet of drift, which has caved and nearly filled the opening. The ore is mostly unaltered magnetite. The depth of the pit is about 75 feet.

The Chalifou pit is a small prospect a mile and a half southeast of the Finch on a different horizon from the Arnold hill group. The ore is reported to have a thickness of 8 to 12 feet.

Of the analyses given below, No. 1 has been taken from Maynard's paper already quoted and relates to ore from the Indian mine which lies high upon the ridge. No. 2 which is quoted from the same source represents a sample from the Finch pit. Both analyses are by Maynard and Wendell. No. 3 is an analysis of ore from the Chalifou pit, supplied by Mr S. Le Fevre.

	1	2	3
Fe_2O_3	69.99	81.65	45.45
FeO	8.87	7.87	21.26
SiO_2	14.60	5.60	22.38
TiO_2	.....	.....	.49
S	.24	.24	.045
P_2O_5	.07	.45	.430
Al_2O_3	3.67	2.12	4.76
MnO	.38	tr.	.16
CaO	1.90	1.56	2.22
MgO	tr.	.67	1.95
	99.72	100.16	99.145
Iron	55.91	63.27	48.35
Phosphorus	.03	.196	.188
Manganese	.28	.....	.122
Titanium	.....	.....	.295

Production of Arnold hill mines. In round figures the output of the mines on Arnold hill may be placed at 600,000 tons. Up to 1864 there had been taken out about 150,000 tons and it is estimated that 400,000 tons were mined in subsequent operations previous to the reopening of the property by the Arnold Mining Co.

Palmer hill mines

These mines form a single group. They are situated on an ore body which traverses the hill just below the summit in a northeast-southwest direction and has been explored for nearly half a mile on the outcrop. The strike brings them nearly in line with the Jackson hill deposits, a mile distant to the northeast. The several pits that have been used for ore extraction in years past include the Elliot and White Flint on the western side, the Big, Summit and Lundrigan pits in the central portion and the Little pit and Lot 29 on the east.

The period of active operations began about 1825 and lasted till 1890. The property was held as an undivided interest by the J. & J. Rogers Co., and the Peru Steel & Iron Co., who converted the ore into charcoal blooms at their forges at Ausable Forks, Black Brook, Jay and Clintonville. It is worthy of note that a separator in which magnets were employed for removing the magnetite in the crude ore was erected on Palmer hill in 1836, one of the first experiments with this process that has been recorded. Evidently the attempt was not wholly successful, as the process was later superseded by gravity methods.

Geology. The ore body consists of a band or zone impregnated with magnetite. It is on the whole leaner than the Arnold hill deposits owing to the mingling of the magnetite with the minerals of the adjacent walls. The latter are also not so sharply defined. The magnetite is distributed more or less evenly throughout the mass, or gathered into bodies that are relatively rich. In mining the higher grade ore was specially sought for and was followed in preference to the excavation of the whole deposit.

The rock on Palmer hill derives special interest from a petrographic standpoint owing to the occurrence of fluorite. This mineral is seemingly an original constituent. It forms irregular grains of about equal size with the feldspar and quartz and intercrystallized with them. Where most abundant it constitutes from 25 to 50 per cent of the rock. It is particularly in evidence in the walls of the Big pit and in a belt which can be traced north from

the pit for 150 feet. The containing rock has a granitic texture and in other respects is analogous to an acid intrusive.

Two diabase dikes, each about 15 feet thick, cut the ore. One of these runs nearly parallel to but west of the outcrop, standing as a vertical wall when seen underground. It sends off a small offshoot from the eastern end but holds its width undiminished so far as it can be traced. The second dike intersects the deposit at the Big pit, crossing at an oblique angle and continuing in a northerly direction over the summit of the hill. The dikes have exerted noticeable contact effects upon the ore in the development of a black garnet (brown in thin section), which has been formed at the expense of the magnetite and feldspar, as well as by rendering it dense and exceedingly hard. A considerable quantity of the garnetiferous ore can be found on the waste dumps, having proved evidently too refractory to be used.

Description of workings. The ore body has been excavated for a long distance as an open pit, with chambers extending down the dip when the depth became too great for removal of the overlying rock. In places the surface workings have caved and are inaccessible. The Elliot slope enters the hill on the southwestern side at a little over 900 feet elevation. It pitches nearly north. The slope was the last one opened and is said to follow a shoot of ore 9 feet thick. The adjoining White Flint slope, somewhat higher up, also pitches north at an angle of 70° at first, but flattens downward; it is bottomed at 1200 feet. The breast of ore, judging from the visible part of the excavation, must have measured about 20 feet. The ore contains a good deal of milky quartz, but is rich compared with the general average. Between this and the Big pit the north-south dike intervenes and the ore body swings off toward the east. The Big pit is the deepest of all, 2200 feet on the dip which begins at 60° and is nearly horizontal at the bottom. The Summit pit at the highest point of outcrop of the deposit is credited with a depth of 1000 feet and dips about 30°. Of the other workings, the Little pit, opened by the Peru Steel & Iron Co., and lying near the eastern end, is the largest. The slope has a length of 1200 feet and follows a shoot 10 feet thick and 100 feet wide across the dip.

Character of the ore. In texture the ore is rather fine. Its appearance and mode of occurrence is much like the Lyon Mountain ore. The gangue consists mostly of microcline, orthoclase and quartz, with a very small proportion of ferromagnesian minerals in the form of augite and biotite. Phosphorus and sulfur fall within the Bessemer limits. The chemical composition is shown by the

following analyses which have been communicated to the writer by Mr W. Carey Taylor.

	1	2	3
Fe_2O_3	46.152	49.757	67.274
FeO	20.735	22.354	30.224
SiO_2	31.700	26.134	3.000
S	.008	.016	.080
P_2O_5	.005	.016	.165
Al_2O_3	1.076	1.531	.....
MnO	.037	.090	.....
CaO	.364	.315	.....
MgO	.872	.229	.....
	100.949	100.442	100.743
Iron	48.43	52.22	70.60
Phosphorus	.002	.008	.07

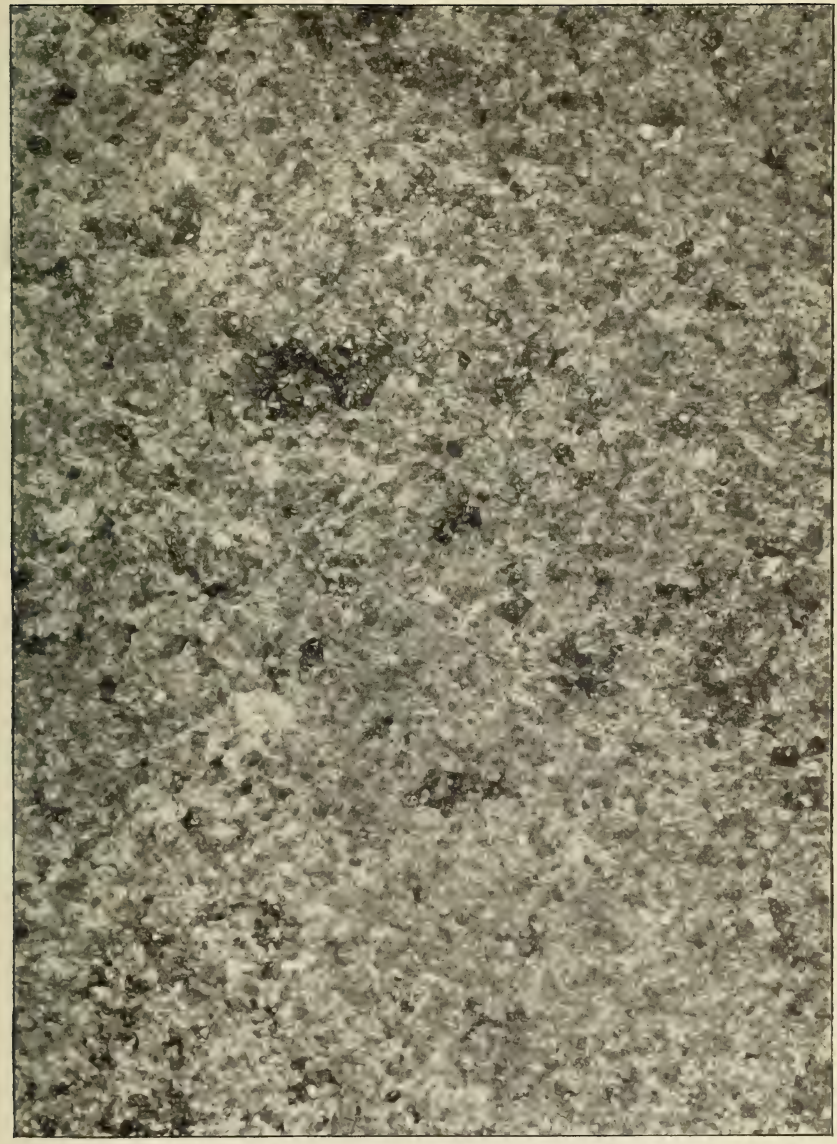
Analyses 1 and 2 are of crude ore from the mines of the Peru Steel & Iron Co., at the east end, and No. 3 of concentrates made by the same company. The higher phosphorus found in the concentrates proportionately to that shown in the analyses of the ore is abnormal and contrary to the usual experience in the treatment of magnetites, at least by magnetic methods. The concentration practice at the Palmer hill mines consisted in first roasting the ore so as to render it more friable and then crushing by stamps and passing the broken ore over jigs. The bloom iron made by the companies was mostly shipped to Pennsylvania for manufacture into crucible steel.

Production. The output of the mines owned by the J. & J. Rogers Co. averaged about 25,000 tons annually for a period of 40 years. The production by the Peru Steel & Iron Co. is not known, nor the quantity mined before the organization of the two companies. It is safe, however, to estimate the total yield at over 1,000,000 tons crude ore. The average assay in iron may be placed at about 40 per cent.

Other mines in the district

Jackson hill. The mines at this locality are based on two or three parallel bodies that outcrop north and south of the road leading from Palmer hill. They lie on the western side of the hill at from 1000 to 1150 feet elevation. Their course is n. 20° e. and dip high to the north. The two main pits are each about 500 feet long and

Plate 10



Fluorite granite from Palmer hill. White particles are fluorite, gray are feldspar and the black crystals are magnetite. A lean ore grading into rich magnetite

10 to 12 feet wide, with an extreme depth of 100 feet. In its association and nature the ore is much the same as the Palmer hill ore and it is said to have yielded equally good iron.

Dills & Lavake and Rutgers pits. The openings are situated 3 miles north of Palmer hill at an elevation of about 1400 feet, as nearly as can be determined. They are just without the limits of the Ausable topographic sheet. The Dills & Lavake is an open cut 100 feet long and 15 feet wide. The Rutgers pit north of this is nearly circular, 30 feet in diameter and about that in depth. The ore is somewhat richer than the average for Palmer hill. It contains apatite in plainly visible grains, indicating a high phosphorus content. The following incomplete analyses have been furnished by Mr J. N. Stower. No. 1 refers to a sample of ore from the Dills & Lavake pit and No. 2 to a sample from the Rutgers:

	1	2
Iron	50.60	50.10
Sulfur	.003	.022
Phosphorus	.64	.341
Titanium	.45	.45

Cook mine. On the ridge east of Arnold hill the gneiss series is well exposed. Much of it is the reddish microperthitic nearly massive variety that has been described as the predominant formation of the district, but there is less augite and oftentimes very little quartz present. In the vicinity of the Cook mine the dark constituent is biotite and the rock has the composition of syenite. A coarse quartzose hornblende variety, which looks like a sheared granite, is found in small patches that may represent later intrusions; it has a fresher appearance than the syenite and the borders are commonly pegmatitic.

The Cook mine, mentioned by Emmons as having been exploited several years before the date of his report, supplied ore to forges on the Little Ausable. It was last worked in 1856 when the forges were carried away by a flood. Two pits evidence these early operations. They are situated on the western side of the ridge nearly opposite the Nelson Bush shafts on Arnold hill. The elevation is about 1000 feet. Both are surface strippings, of which the larger exposes a breast of ore about 12 feet from wall to wall. They have a north strike and a dip 80° west. The smaller parallel pit lies above separated by 30 feet of rock. Emmons records that in exploring the deposit by a transverse trench four veins were encountered with thicknesses of 2 feet, 3 feet, 6 feet and 13 feet respectively.

The ore in places is a compact rich magnetite, yet the greater portion as exemplified by sampling the deposits consists of disseminated grains or stringers of magnetite in a gangue of hornblende, biotite and quartz. Apatite shows in some specimens. The analyses, however, indicate a phosphorus content that is well within the Bessemer limits. The following were made by Mr James Brakes, probably from selected material.

Fe_2O_3	60.226	57.857
FeO	27.486	29.314
SiO_2	7.640	5.400
TiO_2	.410	.492
S	.033	.037
P_2O_5	.052	.023
Al_2O_3	1.269	3.960
MnO	.104	.051
CaO	1.100	1.560
MgO	1.587	.846
	99.907	99.540
Iron	63.536	63.300
Phosphorus	.023	.010
Manganese	.081	.040
Titanium	.246	.295

Battie mine. This is located on a continuation of the Cook ore body, about 1½ miles north of that mine. From Emmons's account, the existence of two parallel deposits is inferred, though only one is shown by outcrop or workings. The mine was last operated about 50 years ago. It is an open cut about 600 feet long and 10 to 20 feet wide. The ore shows much variation across the dip, bands of massive magnetite alternating with rock that carries a greater or smaller proportion of magnetite in disseminated grains. It has a sheeted structure evidently due to slight movements along the walls. They are noticeably grooved and polished. The principal gangue mineral is biotite. The ore is said to have yielded good iron, similar in quality to that made from the Cook ore. Its general character is shown by the analyses below which have been communicated by Mr J. N. Stower. The analyses were made by James Brakes from samples taken at different places along the outcrop. The high titanium, reaching over 2 per cent in No. 5, is

noteworthy, but seems to be traceable entirely to the presence of titanite.

	1	2	3	4	5
Iron.....	52.10	60.70	52.80	39.90	61.20
Phosphorus.	.012	.008	.029	.028	.012
Sulfur.....	.035	.021	.035	.019	.026
Titanium...	.225	.495	.225	.225	2.076

Winter mine. The mine is situated 1 mile northeast of Clintonville near Lilly pond. There are three or more small bands of ore outcropping in a course somewhat west of north and standing vertically or nearly so. The main band is about 10 feet wide. It has been worked by open-cast methods on the south end, while on the north it has been followed by a slope which extends into the hill for about 100 feet where it connects with an adit driven along the course of a diabase dike from the east. Beyond the entrance of the adit the workings are no longer accessible, but apparently the ore body flattens out to nearly horizontal. The relations, however, are obscured by the numerous dikes which intersect the workings. Three of these are found crossing the main slope, the largest lying along the axis of the adit already mentioned. The ore contains much white quartz; an incomplete analysis is here given.

Iron.....	46.70
Silica.....	32.75
Sulfur.....	.024

Mace mine. This is based on a small deposit situated north of the Winter mine. It has been worked principally as an open pit, which has a length of about 500 feet. The width ranges from 3 to 10 feet. The ore is lean and, except for its larger proportion of magnetite, resembles the wall rock. The latter is a hornblende gneiss of granitic appearance.

LYON MOUNTAIN MINES

The Lyon Mountain or Chateaugay mines are in the town of Dannemora, near the western border of Clinton county. The central point of the group is Lyon Mountain, a settlement limited almost entirely to mine employees and their families, situated on the Lake Placid branch of the Delaware & Hudson Railroad, 37 miles from Plattsburg.

In size the mines are among the largest in the State. They are widely reputed also for the high quality of their product. The ore

is all shipped in the form of concentrates which carry minute quantities of sulfur and phosphorus, much below the limits admissible for Bessemer ores. It is used in the manufacture of special grades of iron. Owing to the scarcity of such ores in this country, a steady market has always been obtained for the output.

The first mining of importance within the district was undertaken about 1871 at a locality said to be near the site of the present shaft 4, on the southwestern section of the main ore body. There is evidence, however, that the deposits had been known to the early settlers in the region and some ore was taken out many years before that date. Operations during the early period were carried on by contractors working under leases. The ore was sorted by hand, or crushed and separated in crude mills that had been built in the vicinity, and hauled by wagon to Catalan forges located at Belmont, Russia, Clayburg and Altona where it was made into bloom iron.

In 1879 the Plattsburg & Dannemora Railroad was extended to Lyon Mountain, affording facilities for shipment of the ore to more distant points. Soon afterward the Chateaugay Ore & Iron Company, which consolidated the different mining interests, instituted a more systematic plan of operations that resulted in a largely increased output. In place of open-cast methods, which were first employed, slopes were sunk in the deposits at frequent intervals and the ore mined underground. The number of slopes was increased until over 20 had been located on an outcrop of 3600 feet. The ore was mined on both sides of the slopes with occasional pillars left for support. But after the workings had obtained some depth it became necessary to adopt a different plan; levels were run at intervals of 50 feet vertically while only 6 or 8 of the slopes were used for hoisting purposes. In connection with the mines the company operated shaft furnaces at Plattsburg and Standish for making charcoal pig. The latter furnace has recently been converted so as to employ coke as fuel and is in operation at the present time.

Since 1903 the mines have been under the ownership and management of the Chateaugay Ore & Iron Department, a subsidiary of the Delaware & Hudson Railroad. They have recently been greatly improved upon the basis of a comprehensive scheme which if fully carried out will materially enlarge their production. The recent betterments to the plant include a mill of 1200 tons nominal capacity, doubling the former milling facilities, and the installation of a large central electric station for supplying power to the mines and mills. The accompanying map shows the general fea-

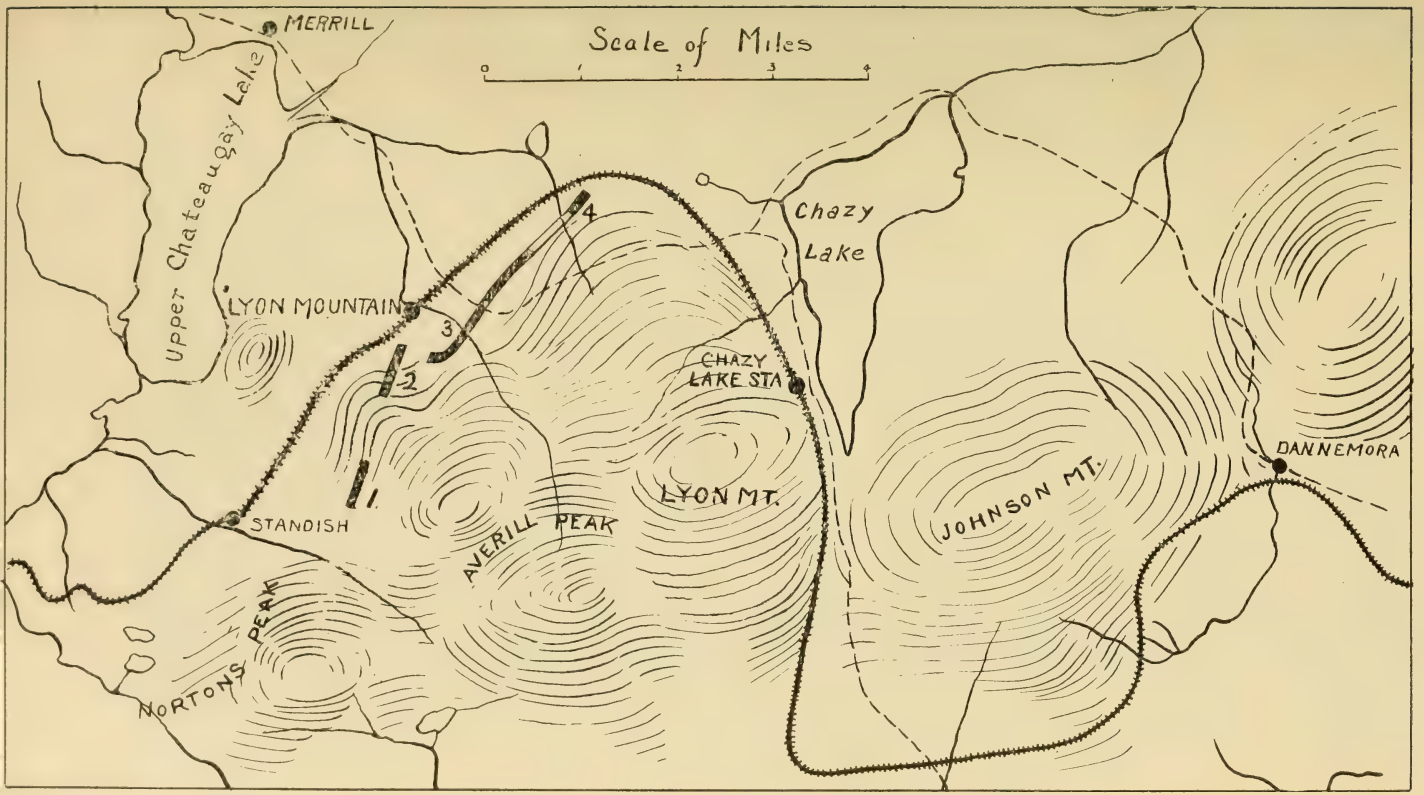


Fig. 17 Lyon Mountain. Sketch map showing distribution of ore bodies

tures of the topography about Lyon Mountain and the distribution of the magnetite deposits. The deposits indicated by the numbers on the map are as follows: 1, Standish or 81 mine; 2, Phillips vein; 3, Main group; 4, Parkhurst.

General geology

The several prominences, which include Lyon mountain in the middle, Averill peak and Morton's peak on the western flank and the Dannemora mountain on the east, constitute the main axis of elevation in this section of the Adirondacks. Towards the east the ridge is succeeded by the narrow abruptly sloping plain of Lake Champlain, while on the north the elevations gradually die out beneath the broad plain of the St Lawrence. Lyon mountain, the culminating point, rises to an altitude of 3,800 feet, and is the most conspicuous landmark in the northern Adirondacks. The ridge is separated from the parallel one to the north, known as Ellenburgh mountain, by a valley 5 or 6 miles wide, the floor of which lies at an elevation ranging from 1500 to 1700 feet. On the west the valley contracts owing to a line of spurs which offshoot from Averill peak in a northwesterly direction. Upper Chateaugay lake which receives the drainage of the valley lies in the western part while Chazy lake is on the eastern side of a low ridge that extends northeast from Lyon mountain.

The higher ridges mentioned above mark the limits of the gneisses and associated crystalline rocks in the northeastern Adirondacks. As they fade out into the bordering plains, the crystallines are succeeded unconformably by Paleozoic sediments which extend over the remaining area as far as the shores of Lake Champlain and the St Lawrence river. The present line of contact between the two series is well up on the outer slopes of the ridges but follows the main valleys for considerable distances into the interior.

Paleozoic rocks. Within the area under discussion the Paleozoic strata are of little areal importance. A narrow belt of Potsdam sandstone occupies the lower part of the depression between Ellenburgh and Dannemora mountains extending as far as Chazy lake and to an elevation of about 1500 feet. Another Potsdam area occurs on the northeastern border of Dannemora township where it is found as high as 1700 feet. According to H. P. Cushing,[1] who has mapped the areas, the rock is a reddish arkose quite different from the coarse phase usually occurring at the base of the formation.

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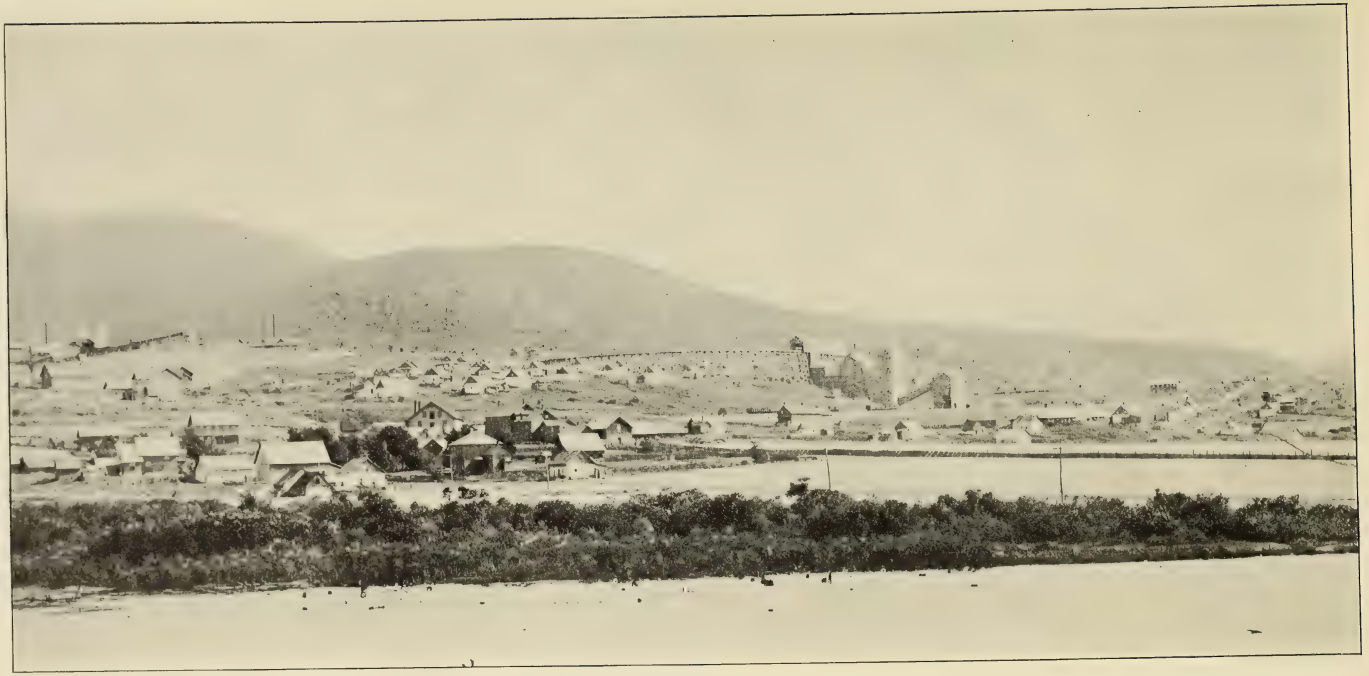
1 Geology of Clinton County. N. Y. State Mus. 49th An. Rep't. 1898. 2:537. *Also* Geology of Rand Hill, 53d Mus. Rep't. 1901. 1:63.

Plate 11



General view of Lyon Mountain. The mines lie part way up the slope of the first line of ridges in the background

Gneiss series. The gneisses are the most widespread of the rocks represented in this region. With the exception of the numerous but comparatively limited exposures of dike rocks which are hereafter described, they comprise practically all of the crystallines adjacent to the ore bodies and occupy as well most of the surrounding country. The occurrence of gabbro and augite syenite has been noted at Rand hill, east of Dannemora mountain, but so far as observed they do not appear anywhere in the immediate vicinity of Lyon Mountain.

In this series is included a complex of rocks differing in composition and physical characters. The study of their field relationships is attended with much difficulty owing to the heavy mantle of drift over the area affording limited opportunity for observation, and to the variations in the rocks from place to place. Practically all of the numerous specimens taken from typical exposures in the vicinity of the ore bodies may be classed, however, in the following groups.

Augite gneiss. This is a reddish or grayish granular rock characterized by the presence of augite. It is mentioned by Cushing as one of the predominant types in the group of gneisses designated as the Saranac formation.

In its prevailing development it consists essentially of feldspar, quartz and augite, with subordinate hornblende, titanite, magnetite and apatite. The augite is an emerald-green variety and is always abundant, sometimes composing as much as 20 per cent of the rock mass. The feldspar is mostly orthoclase, but small amounts of plagioclase (oligoclase) may be present. The orthoclase shows a microperthitic intergrowth with albite. The quartz is a fluctuating constituent, though the relative quantity is below rather than above the proportions found in typical granites. The greenish, strongly pleochroic hornblende occurs in skeletal or very irregularly bounded anhedra and may be in part derived from the augite with which it is intimately associated. Of the other components titanite alone has importance. Most specimens exhibit this mineral abundantly distributed in the form of rounded grains varying from light yellow to reddish brown in color. It also occurs as rims surrounding the magnetite. In some specimens taken from the walls of the ore bodies, the titanite constitutes fully five per cent of the rock mass.

The field appearance of the gneiss is usually massive, with but faint tendency toward a parallel grouping of the constituents. Though it has undergone more or less crushing which has broken

down the feldspar into granular aggregates, it seldom shows any well developed schistosity. Near the ore the gneiss is seamed through and through by pegmatite of lighter color and is also penetrated by a fine-grained granite like that found on Birch hill. Bands of somewhat darker appearance are not infrequently intercalated in the gneiss. They are apt to be more hornblendic than the surrounding rock and are probably to be interpreted as masses of the hornblende schist, which is described on a following page, that have been penetrated by, and, to a greater or less extent, incorporated with the augite gneiss. The origin of the latter rock is believed to be igneous; in physical character and mineralogy there is a close accord with the plutonic rocks such as are found among the basal formations of the Adirondacks. That it belongs probably to the older series of this class is indicated by its cataclastic texture along with the presence of similar intrusives in the vicinity that have been but little affected by dynamic agencies. Though the chemical constitution of the gneiss has not been determined by analysis, there would seem to be little doubt that the relative proportions of the constituents agree with those of the acid igneous class, varying from syenite to a low-quartz granite.

This gneiss underlies the greater part of the area about Lyon Mountain. It constitutes most of the high ridge east of the ore bodies as well as the projecting spurs, and probably extends beneath the drift-covered valley to the north and west. It forms the walls in most of the mine openings and is invariably closely associated with the ore.

Granitic gneisses. On the top of Lyon mountain a coarse quartz-feldspar rock of slightly gneissoid appearance is exposed over an area that can not be accurately delimited, though it is probably small. Judging from surface indications it extends a few hundred feet down the slopes, which are thickly strewn with its boulders, but no contacts were found. The rock has the composition of an acid granite, with which it is allied so closely in texture and field structures as well, that little doubt of its igneous nature can exist. Its mineralogy is simple, feldspar and quartz forming almost the whole mass. The latter mineral occurs in flattened lenses and spindles which have a common orientation and give the somewhat indefinite gneissoid appearance observable on weathered surfaces. Microcline predominates over orthoclase, the two feldspars represented. Both show commonly a microperthitic habit. Of the ferromagnesian minerals there are a few scattered grains of green augite and small shreds of biotite. In outcrop the rock exhibits a

massive habit with the regular jointing peculiar to deep seated intrusives. While there are no supporting evidences of inclusions of contact effects, it is regarded as igneous and probably later than the augite gneiss.

A second type of granitic gneiss, related to the preceding in mineral character but possessing a thorough cataclastic structure, was found on Birch hill between Lyon Mountain and Upper Chateaugay lake. The feldspar consists of microperthite, orthoclase and microcline, all of which have been crushed and finely granulated, though an occasional larger crystal particle is inclosed in the crushed materials. The quartz is drawn out into thin bands. Much magnetite occurs in shreds and irregular grains distributed through the mass or more frequently aggregated along parallel lines which may be continuous for some distance. Except for a little secondary biotite there are no ferromagnesian minerals present.

Hornblende schist. A dark hornblende schistose rock is occasionally found in small patches and lenses surrounded by the augite gneiss. It has a more schistose appearance than any of the other rocks and is also conspicuously banded. The principal mineral is dark green hornblende. The feldspar includes both orthoclase and plagioclase in about equal proportions. The remaining minerals comprise scapolite and titanite, the latter constituting at times fully 10 per cent of the mass, and small quantities of augite, biotite, magnetite and apatite.

Lithologically the schist is quite like the schists that accompany the series of sedimentary gneisses and the crystalline limestones. No exposures of limestone were found, but in limited areas like those at Lyon Mountain it is often absent. At the Williams pit the schist forms both walls of the deposit as a comparatively thin band that is intercalated in the augite gneiss with the axis of extension parallel to the general strike. It is seamed by layers of lighter colored gneiss and shades off at the edges into the augite gneiss through a gradual exchange of the hornblende for the augite and the appearance of microperthitic feldspar. On the hanging side of the deposit, the schist incloses a seam that is made up almost entirely of garnet, a black, nearly opaque submetallic variety, evidently high in iron. The same schist was noticed in the walls at the Dickson open cut, and much of it occurs in the rock dumps at Parkhurst shaft though not observed there in place. These observations indicate that a considerable mass of the rock, probably in interrupted bands or lenses, is inclosed by the augite gneiss in proximity to the ore zone.

Dikes. A minor feature of the geology of the region is the occurrence of dikes which are specially common in the vicinity of the ore bodies. They belong to two series of intrusions, an older represented by granite and a younger consisting of diabase.

The granite dikes vary from a few inches to several feet in width. In appearance they resemble the reddish gneiss, from which they can be distinguished, however, quite readily by their finer and more massive texture. Mineralogically they consist of quartz and feldspar, with subordinate augite, magnetite, titanite and zircon. The feldspar is prevailingly orthoclase, but a triclinic variety, probably oligoclase, is usually present. The dikes are almost identical in composition with the Birch hill granite which strongly points to the conclusion that the two rocks are genetically related. The granite dikes can be best observed at the Williams and Burden openings. At the former locality there are several running parallel to or slightly diverging from the course of the ore body. The only contact effect consequent upon the intrusion of the dikes is a slightly bluish tint assumed by the magnetite.

The diabase dikes occur in numbers both on the surface and in the underground workings. They range up to 15 feet thick, the largest one observed being near slope 15. They do not follow any one direction, though the majority of them have a nearly east-west strike, while most of the others run about n. 30° w. New dikes are frequently encountered in the course of the mining operations.

The petrography of the dikes has been described by Kemp and Marsters,[1] who state that they are all diabase, though showing some variation in individual cases. One dike from the Hall slope is said to be characterized by the presence of small hornblende crystals in addition to those of augite, showing a transition to camptonite. The writer's observations are in accord with the view cited as to the diabase nature of the dikes. With one or two exceptions examination of thin sections revealed little that is noteworthy in their composition or texture. A small dike from slope 4 is characterized by a pronounced porphyritic habit due to the inclusion of augite phenocrysts in a fine ground mass of augite and plagioclase. Some dikes are peculiarly rich in magnetite which has probably been absorbed from the ore bodies during the period of intrusion. This mineral frequently takes the unusual form of long needles which are arranged in parallel groups crossing one another at

[1] The Trap Dikes of the Lake Champlain District. U. S. Geol. Sur. Bul. 107. 1893. p. 447–48.

definite angles. The large dike near Slope 15 is a mica diabase containing abundant biotite in the place of augite which is the normal ferromagnesian mineral.

Geology of the ore bodies

The ore bodies as previously stated are closely associated with the augite gneiss, which is strongly developed throughout the district and belongs to the Saranac formation. So far as the relations can be observed in mine workings and outcrops, they appear to lie in immediate contact with the gneiss throughout most of their extent, the only exceptions being at the Williams and Dickson pits (and possibly the Parkhurst mine) where they are bordered for some distance by schist. The latter rock is limited to small bands included in the augite gneiss.

The bodies consist of parallel zones of the gneiss, in which magnetite forms a relatively large proportion of the mass. The zones possess a marked persistency along the strike and on the dip, which with their small lateral dimensions gives them a prevailing tabular shape. In structural arrangement they conform closely to the foliation of the gneiss. Their geologic horizon appears to be approximately a constant one, as they are alined in a general northeast-southwest direction, parallel to the main strike of the region.

The borders of the deposits are not sharply defined. Stringers and disseminations of magnetite extend into the gneiss for some distance, forming zones of lean ore on either side of the main bodies. This gradation is, however, a variable feature more evident in some places than others. The gneiss itself shows no noteworthy change as the ore bodies are approached.

In character the deposits possess much uniformity throughout their extent. The present main workings at Lyon Mountain are practically continuous along the strike for a distance of 4000 feet, with few variations noticeable in the occurrence or distribution of the ore. In this respect they are in contrast with most magnetite bodies which have been found to show frequent irregularities, specially in form, from place to place.

The ore is a mixture of magnetite and gangue minerals, the latter mostly feldspar (orthoclase, microperthite, microcline and oligoclase), augite, hornblende and quartz. The different constituents may be intermixed so as to show an even distribution, but more frequently perhaps they have a rudely parallel arrangement, that simulates the gneissoid structure of the wall rock. This is par-

ticularly noticeable on weathered outcrops where the narrow bands of magnetite stand out in relief like small veins. The magnetite occurs in granular particles, or irregular masses made up of many grains, with rarely any tendency toward crystal development. When specimens are examined under the microscope the particles are seen to occupy the interspaces, occurring on the borders of the other minerals or completely inclosing them, a relation which suggests that they have been the last to form. A few small crystals of magnetite having octahedral boundaries are generally observed in the slides and are doubtless of an earlier generation. In the average ore there are about equal proportions of magnetite and gangue minerals. Among the less important components of the ore may be mentioned apatite, titanite, zircon and pyrite; they constitute only a minute percentage of the mass as shown by the analyses. At the Williams pit, a black almost opaque garnet was found in the form of rounded grains mingled with magnetite, near the contact of the ore body and the schist of the hanging wall; this mineral has not been observed elsewhere.

Pegmatite is abundant in the ore bodies. The common variety has a reddish color and is composed of alkali feldspar, augite, quartz and magnetite, resembling the augite gneiss except for its coarser more massive texture. Occasionally it contains a sufficient quantity of magnetite to be considered an ore. Another variety of pegmatite is made up of deep red crystals of microcline with plagioclase, scapolite, augite, hornblende, epidote, quartz and magnetite. The epidote is partly an alteration product of the plagioclase feldspar which is probably oligoclase. The pegmatite occurs in bodies that rarely possess any regularity of outline like dikes, though this may be due to the squeezing and shearing it has undergone. Large interlocking masses of hornblende and augite anhedra occur in both varieties of pegmatite. During the course of mining operations vugs and cavities are frequently opened within the pegmatite masses and some have afforded remarkable groups of well crystallized minerals.

Distribution of the deposits

The ore bodies which have been mined on a commercial scale lie within a narrow belt extending northeast and southwest along the eastern edge of the valley. They have been proved by magnetic attraction and borings to constitute a nearly continuous series with a linear extent of some 5 miles. The several openings in the belt comprise mine 81 on the southern extremity, the main

group of workings in the near vicinity of Lyon Mountain, and Parkhurst shaft which lies about 2 miles northeast of the latter.

Mine 81. This mine is a little over 2 miles in a direct line southwest of Lyon Mountain on the southern face of a prominent ridge which offshoots from Averill peak toward Upper Chateaugay lake. The deposit strikes n. 20° e. into the ridge. It is reported to have been traced by magnetic readings across the ridge toward Lyon Mountain and its strike brings it in line with the Phillips ore body west of the main group. It has been mined along its course for a distance of 1000 feet or more. At present the only accessible workings are two drifts near the surface, the shafts being dismantled and filled with water. The eastern drift which lies higher upon the ridge is approximately 600 feet long and from 25 to 75 feet high, and is open cut for some distance from the entrance at the south end. On the western section there are three shafts, with a drift from the central shaft extended in the direction of the first, but at a slightly lower level. Two of the shafts have been carried down to a depth of 400 feet and a series of levels was opened shortly before the mine was abandoned. The ore averages about 18 feet thick with only minor pinches and swells. It stands nearly vertical, inclining slightly to the east in some places and in other parts slightly to the west.

The adjoining gneiss is the augite variety, almost massive and carrying little quartz. Specimens from near the contact show abundance of titanite and some hornblende. There is little or no gradation along the walls; practically the entire width of the ore zone is occupied by the workings.

Several dikes are found in the eastern drift. They are all diabase. The smallest is about 3 inches and the largest about 3 feet wide. Their direction is northwest-southeast, except in one instance near the heading of the drift where a 2-foot dike occurs on the north side of the ore body running nearly parallel to it. According to local records, the mine was the first one to be explored in the Lyon Mountain district and was worked to some extent as early as 1840. No systematic mining was undertaken, however, until 1878 when the western drift was opened. The eastern drift was opened in 1880. The ore was hauled by wagon to the forges at Clayburg. According to Smock, mining was suspended about 1885; but operations were resumed a few years later and continued up to 1902, since which time the mine has been idle.

The ore does not differ in appearance from the general run of the mines at Lyon Mountain. It is a granular aggregate of magne-

tite, feldspar and augite. The feldspar is mostly oligoclase, with subordinate orthoclase. Incomplete analyses quoted by Putnam, No. 1 from a sample of 300 tons crude ore and No. 2 from 150 tons concentrates, show the following percentages:

	1	2
Iron	34.81	65.14
Titanic acid	nil	pres.
Phosphorus	.041	.017

The sulfur was not estimated. The percentage of phosphorus in both crude ore and concentrates is somewhat higher than the average obtained from present operations at Lyon Mountain, yet the concentrates are superior in this respect to most Bessemer ores. Determinations made on 33 samples of drill cores taken from different localities, reported by Mr H. H. Hindshaw, gave an average of 41.87 per cent iron and .025 per cent phosphorus.

Main group of mines. The ore deposits now under operation at Lyon Mountain comprise the middle section of the belt on the northwestern slopes of the high ridge. The mean elevation of the outcrop is about 2000 feet above sea level and 300 feet above the floor of the adjoining valley.

In the southern portion of the group three parallel series of deposits occur and are known locally as the front or main vein, the middle vein and the back or Dickson vein. The main vein which is the one most extensively worked has been proved by actual development to constitute a continuous ore body for a distance of about 2500 feet and its further continuity indicated by test pits and magnetic determinations for an additional 2000 feet. The back vein has been opened only on the southern portion; it outcrops parallel to the main vein at a horizontal distance of about 200 feet. The middle vein between the two is undeveloped and little is known about its extent. A plan of the surface and underground workings is shown in figure 18.

It is only in the extreme southwestern part of the group that any evidence of a marked structural break is found. For most of the distance the outcrop follows an almost straight line in a general direction n. 20° e. Near shaft 5, however, a rather sharp fold enters causing the outcrop to swing around to nearly west and this direction is followed for the remaining distance of 1000 feet in which the deposits have been mined. Beyond the Burden open cut which is the most westerly working on the southern wing of the fold the continuation of the ore has not been clearly estab-

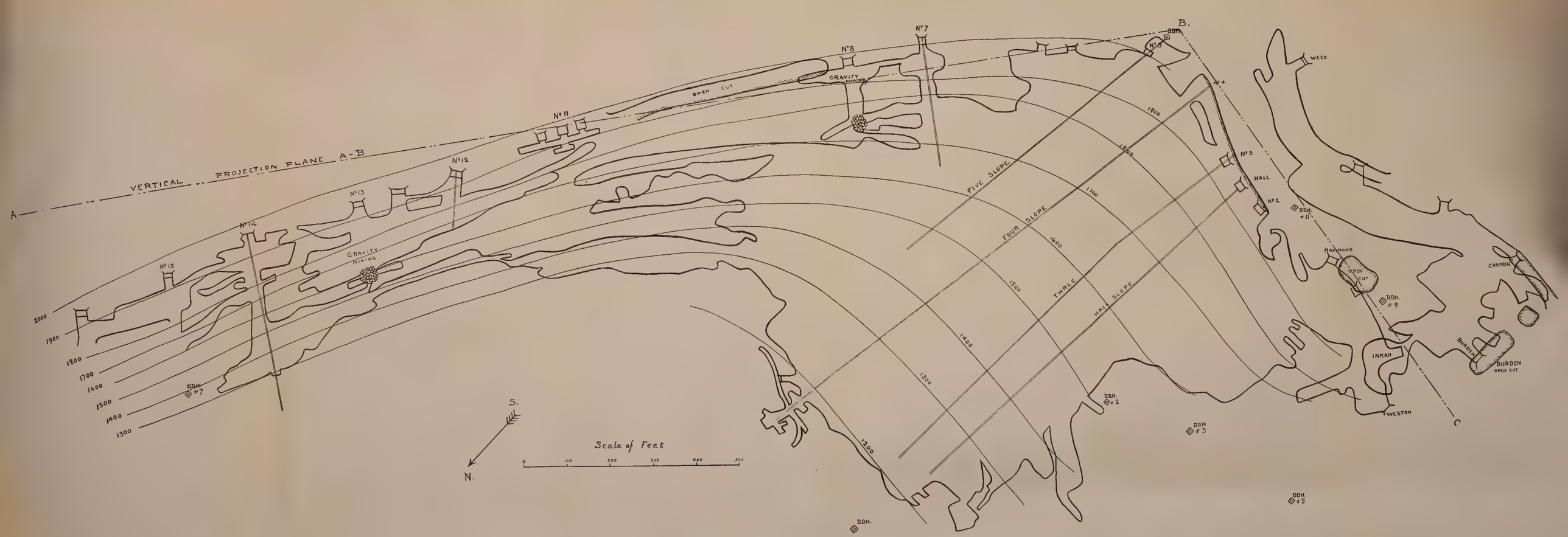


Fig. 18 Plan of main workings, Lyon Mountain

The elevations indicated by contour lines are based on sea level. After a map by N. V. Hansell and H. H. Hindshaw

lished. The geologic relations are obscured by the heavy drift covering the lower slopes of the ridge and the valley floor. The results of magnetic surveys and diamond drill tests, so far as they can be interpreted, indicate the probable interruption of the deposits at a point not much distant from the Burden pit.

Another group of deposits has been shown to occur, though completely buried beneath drift, on a low ridge 2000 feet west of the main group and is known as the Phillips vein. Its northern extremity lies about 2000 feet northwest of the Burden while its trend is southwest toward the 81 ore body. It consists of two parallel veins which correspond quite closely with the front and back veins of the main group and like them have a northwesterly dip. Their position and similarity of relations suggest the possibility that they are a displaced portion of the main ore zone. The existence of a fault with a throw to the northwest would explain the sudden termination of the ore near the Burden pit and may be considered also not improbable owing to the severe dynamic strains to which the strata have been subjected, as manifested by the folding and by the minor flexures and shearing effects that are observable in the adjacent ore bodies and inclosing walls. The indicated throw of the fault is a little west of north, approximately parallel to the axis of the main fold.

Mining operations are confined at the present time to the southern section of the ore zone. In this part there are some 20 slopes or inclined shafts, besides open cast workings, located at intervals along the outcrop of the front and back veins. Beginning at the southwestern extremity, the first openings on the front vein are the Weston and Hammond, then follow in order Nos. 1, 2, Hall, 3, 4, and so on up to No. 16, which is near the old mill. On the back vein are the Burden, Cannon and Dickson pits.

Most of the ore is now obtained by underground mining in the Hall slope and the adjacent slopes 3, 4 and 5, and by open-cut workings at the Burden and Cannon pits. The deepest working is No. 4 which has been carried down to a depth of 1400 feet on the course of the deposit or about 800 feet vertically. The Hall and No. 3 slopes have reached nearly equal depth. The dip of the ore bodies in this section is about 45° north at the surface but gradually flattens downward to 25° or less.

At the Burden and Cannon open cuts the width of the back vein is fully 150 feet measured along the surface. In the bottom of the Hall slope the horizontal drifts are 200 feet wide. Such thicknesses are unusual, however, and in the former instance may be

ascribed to a local bulge that has probably resulted from the folding. The large ore body found in the Hall slope very likely represents the combined front, middle and back veins which have converged in depth. The walls are not well defined in this part, as the ore grades along the contact into the country rock. Between slopes 5 and 16 the main or front vein averages about 20 feet across the dip and is quite regular. The dip ranges from 45° to 60° n. w., being steeper at the north. The main workings here are slopes 7, 8, 12 and 14. A section across the ore bodies on line of the Hall slope is given herewith [fig. 19].

The Williams or 82 mine lies 2000 feet northeast of slope 16 on the prolongation of the same zone. It has not been operated for many years. The workings comprise a shaft 180 feet deep and an open cut extending north of the shaft for a distance of 200 feet. The geologic relations here differ from those in the southern part in that the wall rock is an amphibole schist. The deposit consists of stringers and impregnations of magnetite in the schist, with bands of lighter augite gneiss intercalated parallel to the foliation. The ore varies in richness across the outcrop. The dip of the strata is 80° northwest at the surface, but is said to incline away from the vertical gradually with depth.

Drill tests. Mention may be made of the diamond drill borings which have been put down to explore the ore bodies and which show their approximate position outside the limits of present workings. A drill hole located on the west side of West Mine street, 1200 feet from the entrance to the Hall slope and in line with its direction, found the ore at 663 feet depth with a thickness of 100 feet. The indicated average dip of the ore body from the outcrop to the point intersected by the hole is thus about 45.°

At a locality on the continuation of the same line but 800 feet farther north, the ore was encountered at 1031 feet and showed a thickness of 74 feet. The dip flattens considerably between the two holes, averaging only 22° for the interval.

On line with slope 15 and 600 feet distant from the shaft a drill hole found the ore at 986 feet with a thickness of 80 feet. The indicated dip is about 60°. A second body of lean ore 20 feet thick was found below the first separated from it by 15 feet of rock.

A negative result was obtained by drilling 700 feet northwest of the Weston pit. The hole was put down 1859 feet but failed to find ore. The position of the hole is somewhat west of a line drawn from the Burden pit, which approximately marks the southwestern limits of the main zone as present known, to the

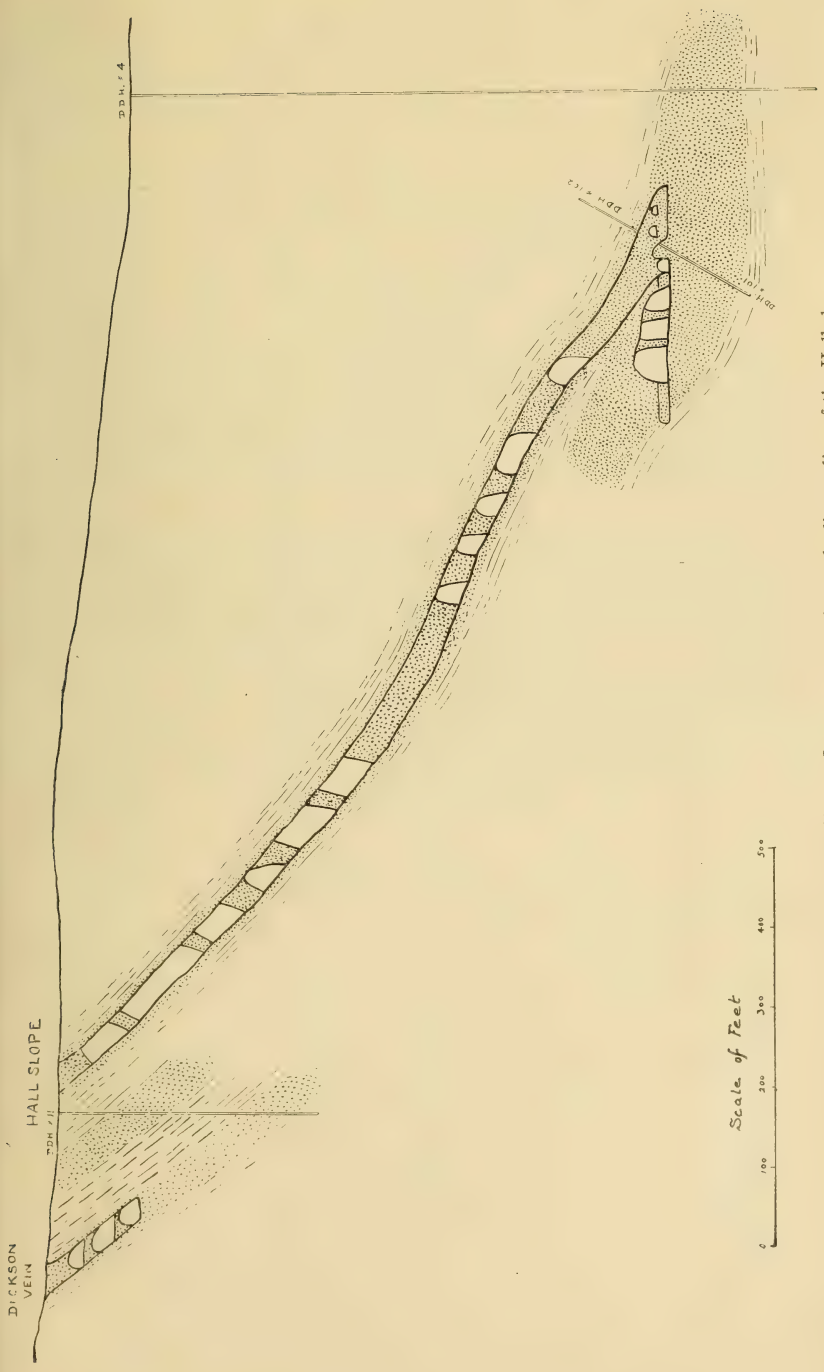


Fig. 19 Lyon Mountain. Vertical section across the ore bodies on line of the Hall slope

indicated northern extremity of the Phillips vein. If the presence of a fault is assumed to account for the relations of the latter to the main zone, the line would coincide with the probable direction of displacement so that the drill hole actually may be considerably above the horizon of the ore bodies.

The Phillips vein has been tested by two drill holes. Two parallel bodies of ore have been found with a thickness of 50 feet. The dip is 80° northwest.

Chemical analyses. There is a wide range in the mineral composition of the ore and consequently in the chemical composition. Some portions of the deposits have only small amounts of admixed gangue minerals so that the iron content may run as high as 50 per cent or even more. The quantity of such ore mined, however, is not large when compared with the total output. On an average the iron runs between the approximate limits of 30 and 35 per cent.

The analyses below furnish the essential details as to the chemical composition of the crude ore and of the concentrates made by magnetic separation as now practised. No. 1 represents a sample of relatively rich ore, such as was formerly shipped without concentration. No. 2 is an average of concentrating ore, and Nos. 3 and 4 of concentrates. For analyses Nos. 2 and 3 the writer is indebted to Mr James Brakes, chemist at the mines. Analysis No. 1 is quoted from an article by James M. Swank published in the volume of the "Mineral Resources" for 1883 and 1884.

	1	2	3	4
Fe_2O_3	47.38	31.48	60.128	63.062
FeO	21.32	15.81	28.850	28.996
FeO (gangue)	.....	2.83	.257	.....
SiO_2	20.89	33.16	6.880	4.740
TiO_2	.....	.427	.417	.....
S	.084	.027	.022	.031
P_2O_5	.057	.043	.023	.012
Al_2O_3	4.02	4.90	.900	.339
MnO	.21	.115	.107	.134
CaO	3.72	4.96	.660	.740
MgO	2.11	2.10	.405	.434
K_2O	.....	1.438	.494	.....
Na_2O	.....	2.283	.777	.....
H_2O	.....	.25	.040	.....
	99.791	99.823	99.960	98.488

Iron	49.750	36.50	64.72	66.695
Phosphorus	.025	.019	.010	.005
Manganese	.162	.089	.083	.104
Titanium	.....	.256	.250	.....

The small quantity of titanium shown in analyses Nos. 2 and 3 is interesting, though metallurgically negligible. It seems to be carried by the mineral titanite which is intergrown with the magnetite. The phosphorus averages about .008 in the concentrates now made.

In the report by Putnam are given the following incomplete analyses of furnace ore and concentrates. The latter were prepared by jigging, a system of concentration formerly employed at the mines. The sample of furnace ore (1) was an average of 22 carloads; that of concentrates (2) an average of 120 tons.

	1	2
Iron	45.21	66.00
Titanium	nil	pres.
Phosphorus	.011	.003

The character of the gangue material, which in a way may be regarded as closely allied to the country gneiss, is shown by the subjoined analysis of tailings from magnetic treatment. The analysis has been supplied by Mr Brakes.

SiO_2	58.56
Al_2O_3	10.72
Fe_2O_3	4.57
FeO	8.36
MgO	4.06
CaO	8.24
Na_2O	2.99
K_2O	1.61
H_2O	.12
TiO_2	.457
P_2O_5	.064
MnO	.124
S	.035
	99.910

It is apparent that the percentage of free silica in the form of quartz must be small. The relative proportions of the chemical constituents agree quite closely with those found in many syenites.

Parkhurst mine. This mine has been opened on the northeastern part of the ore belt. The shaft is about 2 miles from Lyon Mountain station. Within a short distance north of the Williams mine the outcrop of the deposits passes beneath drift and is nowhere exposed over the northern section. There is no interruption in the lines of magnetic attraction, however, so that it seems safe to assume that the ore continues unbroken in the interval which is something over a mile.

The shaft has been put down on the slope of a small hill at a point a few hundred feet east of the railroad and perhaps a hundred feet above it. The shaft was located with a view to striking ore near the outcrop, the line of which had been previously approximated by magnetic determinations. The first work on the shaft was done over 20 years ago. After passing through 70 feet of drift, rock was encountered and sinking was discontinued for a time. Later on a drill hole which had been put down in the bottom of the shaft showed ore at a depth of 145 feet from the surface with an apparent thickness of 48 feet and an average iron content of 40.41 per cent. The shaft was then sunk to the ore and mining begun. In the period of operations from 1889 to 1892 inclusive the output according to company records amounted to about 40,000 tons, of which 37,500 tons was classed as furnace ore and was smelted without concentration in the furnace at Standish.

The shaft is now partially filled with water, preventing access to the underground workings. The character of the rock dumps about the shaft indicate that the walls are made up of a schist similar to that at the Williams mine. There is much pegmatite in both ore and country rock and the existence of one or more diabase dikes is inferred.

The magnetite has a granular texture, coarser than the average of the ore found in the workings farther south, and is intermixed with a gangue consisting mainly of quartz and feldspar. It contains apatite in crystals and grains of macroscopic size, indicating a fairly high phosphorus content. According to analyses that were made during the period of operations, the ore shipped to the Standish furnace averaged 49.73 per cent iron and about .1 per cent phosphorus. The following two analyses furnish additional particulars as to the character of the ore.

The new mill at Lyon Mountain

	1	2
Fe_2O_3	42.157	56.559
FeO	23.096	23.313
SiO_2	23.340	13.700
S	.038	tr.
P_2O_5	.433	.205
Al_2O_3	4.791	1.900
MnO	.129	.....
CaO	4.700	4.390
MgO	1.643	.....
	100.327	100.067
Iron	47.374	55.779
Phosphorus	.189	.095
Manganese	.100	.....

From samples collected recently from the mine dump, the following percentages were obtained, No. 1 being a sample of the rich ore and No. 2 of leaner material:

	1	2
Iron	56.10	34.20
Silica	13.85	34.08
Titanic oxid	nil	.20
Sulfur	.015	.033
Phosphorus	.156	.031
Manganese	.05	.04

Aside from its richer character, the principal feature of the ore from this mine, as compared with that from the other workings of the district, is the relatively high phosphorus which as will be observed exceeds the maximum admissible in Bessemer ores. It is largely for this reason that the present company has not continued exploitation of the ore body.

A magnetic survey of the ground about Parkhurst shaft carried out in 1906 affords strong evidence for the regularity and continuity of the deposit for a distance of at least ½ mile to the northeast of the old workings, while to the southwest the lines of attraction continue without break to the Williams mine and the main group. There is reason for believing also that the deposit here is above the average in thickness. This is indicated by the results obtained in the shaft itself, and is further supported by the record of a drill hole put down about a half mile to the southwest. The

hole referred to is located in a swampy tract 200 feet northwest of the apparent outcrop. It is bottomed at 469 feet. Ore was cut at 185 feet from the surface with a thickness of 167 feet. As the hole is vertical allowance must be made for the dip of the ore body which is not accurately known though it is supposed to be about 40° n. w.

Production of the Lyon Mountain district. The output of the district since the beginning of active work in 1871 may be placed approximately at 3,500,000 long tons. This estimate is based on incomplete records, but it is believed to be not far from the actual total. In the period from 1881 to 1889 inclusive the shipments amounted to 1,539,520 long tons. There are no statistics on record for the period from 1890 to 1900, but in the six years following 1900 the shipments have aggregated 606,573 tons. During the early years the output included a proportion, varying from year to year, of selected ore which was shipped in its crude state and which carried from 45 to 50 per cent iron. This practice was discontinued later on, and the more recent shipments have consisted solely of concentrates, assaying from 60 to 66 per cent iron.

MINES IN THE SARANAC VALLEY

In the towns of Saranac, Black Brook and Dannemora, along the Saranac valley, there are old mines that were once operated in connection with local iron works. During the middle of the last century when the bloomery process of making iron was generally used this section supported one of the largest industries of this kind anywhere in the State, its importance having been due to the great timber tracts which afforded a plentiful supply of charcoal for fuel and to the abundant water power on the Saranac river, one of the principal Adirondack streams. Forges were built along the river at Clayburg, Redford, Russia and Saranac. The ore was drawn not only from the local deposits but from Lyon Mountain and other points many miles distant. The industry was discontinued about 1880 and brought about a cessation of mining in the region, though one or two deposits were worked some time after that date.

Geologic features. The gneiss series is most extensive. In it are represented varieties more or less distinct in their mineralogy and appearance, but of which the augite gneiss described as the ore-bearing formation at Lyon Mountain and the granitic gneisses have the largest areal development. They are characteristic members of Cushing's Saranac formation, indeed the latter takes its

name from their extensive occurrence along the Saranac river in this section.

In his report "Geology of Clinton County," Cushing describes as belonging to a separate type, a silicious gneiss, resembling quartzite in appearance, but composed of microcline and quartz, with garnet and a mineral that corresponds optically to sillimanite. It occurs along Trout brook which enters the Saranac at Russia. From its composition he is inclined to consider the rock a sedimentary derivative and he further suggests that there may be a belt of related gneisses and crystalline limestone within the drift-covered valley. The exposures are insufficient to establish the extent of the sedimentary or Grenville rocks, but it is probable that such a belt exists. Further evidence confirming this view was found by the writer near Clayburg where a biotite schist is exposed along the west bank of the Saranac river. The schist has been injected by granitic materials, though its characters are plainly those of the Grenville series, shown by its crumbling well foliated texture, pyritic inclusions and variation of composition across the strike.

Small areas of gabbro are found at two localities in the district. The largest exposure is just north of Clayburg and is about 50 yards wide; the second outcrop is west of Russia on True brook. They occur as dike intrusions in the Saranac gneisses.

Diabase dikes are numerous. Cushing has listed 26 within the townships of Saranac and Black Brook and several more occur in the mines that have not been recorded. They are the latest of the recognizable igneous rocks.

Of the sedimentary rocks the Potsdam sandstone composes a part of the surface geology of the district, occupying a large area in Saranac township east of the river. It is not exposed anywhere in the vicinity of the ore bodies.

Averill mine. Near Dannemora village are the Averill, Ellis, Fairbanks and Dannemora mines, all of small size. They lie on the slopes of the high ridge which forms the north side of the Saranac valley and of which Dannemora mountain marks the culmination in this part.

The Averill mine is the largest of the group. The ore body is first encountered a few hundred feet southwest of the State Prison and can be traced in a northerly direction for 1000 feet. It is inclosed in a basic hornblende-biotite gneiss, the ore itself consisting of streaks and bands of magnetite alternating with the materials of the wall rock. The latter is cut by reddish granite of which there is a large exposure on the hill back of the prison that has

furnished much of the building material for local use. The granite consists of microperthite and quartz and is rich in magnetite, resembling the type found on Birch hill near Lyon Mountain. The deposit is inclined 10° to the west and has been worked to a depth of about 100 feet. The main openings are on the southern portion, where there is an open pit 300 feet long and 10 to 30 feet wide. Several hundred feet north of the pit a shaft was sunk in the hanging wall, with the intention of mining the deposit, but the shaft was abandoned after reaching a depth of 100 feet. A drill hole put down near the shaft is said to have found ore at 150 feet from the surface. The ore is mostly of lean character, with an average probably of not more than 35 per cent iron. The mine was opened in 1842. For several years it was worked by the State, but was abandoned with the discovery of the Dannemora mine which is located within the prison grounds. The latter mine is no longer accessible.

Ellis mine. This is situated 2½ miles northwest of Dannemora. It is based upon an ore body from 8 to 10 feet wide consisting of disseminated magnetite in reddish granitic gneiss. The strike is about north and south and the dip 15° west. The pit has a length of 50 feet; it is filled with water so that the extent of the underground workings can not be ascertained. Judging from the small amount of rock on the dump, the mine was not very productive.

Fairbanks mine. The Fairbanks mine is about 2 miles west of Dannemora. It was opened nearly 50 years ago and worked for only a brief period. The ore is from 3 to 5 feet thick.

Bowen & Signor mine. This is located on a belt of deposits which show a nearly continuous line of magnetic attraction extending several miles along the Saranac river in the towns of Black Brook and Saranac. The outcrops are concealed for most of the distance by drift and river sands, but the horizon of the ore has been approximately fixed by magnetic measurements. These show a line of maximum attraction which begins 1 mile east of Redford and runs in a broad curve southwest at first to Clayburg and thence westerly and northerly to a point on Cold brook about 1½ miles north of its junction with the Saranac. The principal lines of magnetic attraction are indicated on the accompanying sketch map [fig. 20].

The Bowen & Signor mine lies 1 mile south of Redford on a drift-covered ridge that rises from the south bank of the Saranac. There are some 6 or 8 pits and shafts, now dismantled and filled by caving of surface materials. At the date of Putnam's report the ore had

Cold Brook

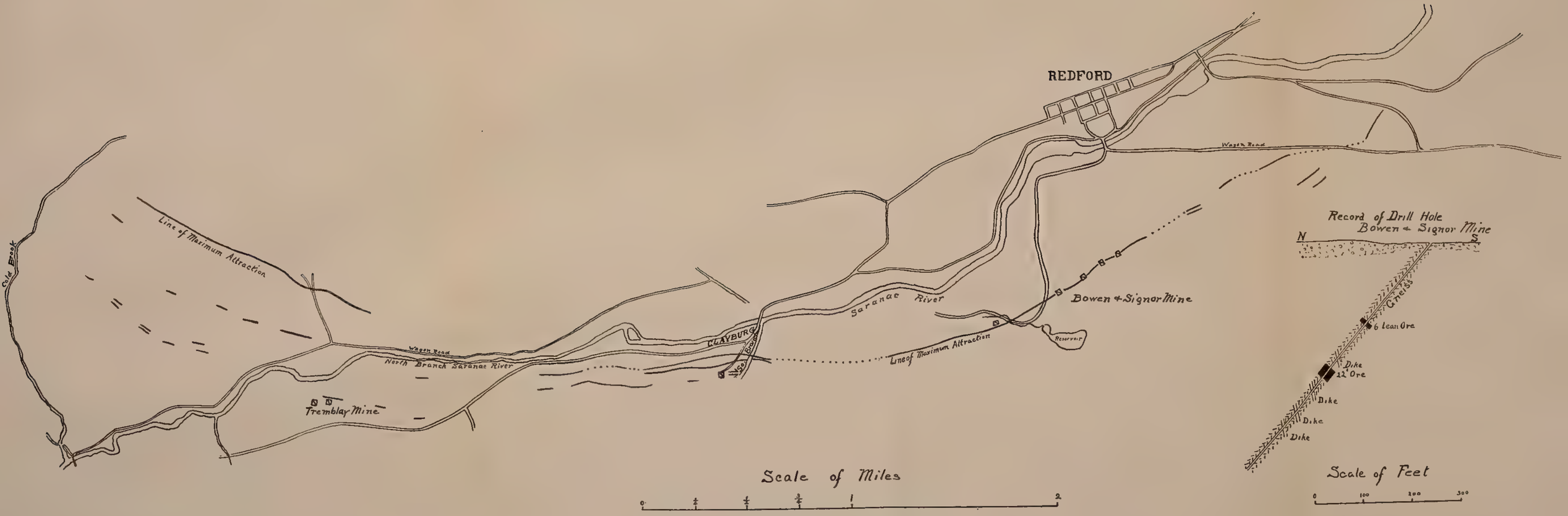


Fig. 20 Mines near Redford and Clayburg and lines of magnetic attraction. After a map compiled by the Saranac Iron Mining Company

been mined for 1600 feet on the first level 100 feet below the surface, while a second level 75 feet below the first had been opened on the west end. The width of the deposit according to the same authority averaged 20 feet, thickening to 30 feet in places. In 1905 the deposit was tested by diamond drilling, the results of which have shown that it is irregular and pinches in places to a thin seam. Of the 12 holes put down along the strike, ore was found in all but three and the maximum thickness was 22 feet which was encountered near the central part of the old workings. On the western end, the body apparently is broken up into several parallel bands. The dip estimated from the data obtained in the drill holes ranges from 45° to 65° east, being steepest on the west. Several diabase dikes intersect the ore body and are said to mark lines of faulting.

The wall rock, judging from specimens collected along the surface, is not the usual reddish granitic variety exposed in the district. It has a light gray color and is made up almost entirely of plagioclase, quartz and magnetite. The plagioclase belongs to the basic end of the series, corresponding optically to labradorite. The composition can scarcely be identified with any common type of igneous rocks, but rather suggests a metamorphosed sediment.

The ore is a mixture of magnetite with hornblende, quartz and pegmatite, the percentage of iron ranging within rather wide limits. The following analyses of crude ore (1) and concentrates (2) are given by Putnam as the results obtained from average samples:

	1	2
Iron	34.28	66.78
Titanium	nil	nil
Phosphorus	.124	.037

From two to three tons of crude ore were required to make one ton of concentrates by the methods of hydraulic separation formerly used.

The output of the mine from its opening in 1855 is reported by Smock at 260,000 tons; though not specifically mentioned the quantity probably represents crude ore.

Clayburg mine. Near the site of the old forges at Clayburg are two pits, the openings of which face toward the Saranac river. The larger pit, on the west bank and somewhat south of the smaller one located on the east side of the river, is several hundred feet long and some 50 feet deep. It is partly an underground drift. The strike is nearly east and west and the dip almost vertical inclining

a few degrees toward the north. So far as can be estimated from the surface the breast of ore must have averaged about 15 feet. The walls in both pits consist of microperthitic gneiss of granitic character with the high percentage of magnetite nearly always present in this rock. No analyses of the ore have been obtainable; the general average is probably about that given for the Bowen & Signor deposit.

Tremblay mine. This deposit is situated in the town of Saranac 2 miles west of Clayburg. The workings which consist of one or more pits are now filled with water so that neither the deposit nor the walls can be seen. Putnam has recorded that in 1880 the main pit was from 150 to 200 feet long and 75 feet deep. Little work was done after that date. The analyses of ore (1) and concentrates (2) are quoted from his report.

	1	2
Iron	28.62	65.01
Phosphorus	.017	.004

ST LAWRENCE COUNTY MINES

On the west side of the Adirondacks, St Lawrence county contains the only deposits of nontitaniferous magnetites that have been extensively mined. The principal workings are at Jayville, Benson Mines, Fine and Clifton in the southeastern part, near the headwaters of the Grasse and Oswegatchie rivers. They are reached most readily by the Carthage & Adirondack Railroad, which affords direct communication with Lake Ontario at Sacketts Harbor and crosses the main railway lines at Watertown and Carthage. The accompanying sketch map [fig. 21] gives the location of the larger deposits.

The deposits were discovered many years ago. Some of them are mentioned by Emmons who did not, however, consider them as available resources at the time owing to their remote situation. On that account they received little attention from the early iron manufacturers of St Lawrence county. Most of the ore used in the old furnaces came from the hematite deposits around Gouverneur and Antwerp. The region about the mines is largely wilderness with few beaten routes of travel.

General geology

The Adirondacks fall by gradual stages toward the St Lawrence plain. The surface in this section has a mean elevation of from

1000 to 1500 feet increasing to the southeast in the direction of the interior uplifts. Though the contours are generally rugged, due to succeeding lines of ridges, there are few notable prominences and the hills rise scarcely more than 500 feet above the valley bottoms.

Fig. 21 Sketch map of the St Lawrence county magnetite deposits. Ore bodies shown by heavy lines

The geology of this part of the Adirondacks has been investigated only in its broad features. No maps adequate for a detailed survey are available, and until they are forthcoming a systematic investigation must necessarily be postponed. It is to the reconnaissance carried out during recent years by C. H. Smyth jr, that

we owe most of our knowledge concerning the subject.[1] Professor Smyth has worked mainly in the outlying sections, including central and western St Lawrence county and eastern Lewis and Jefferson counties, but the salient facts of structure and stratigraphy he has brought to light apply as well to the region under discussion.

The rocks which have widespread development comprise crystalline limestones, schists, gneisses and a series of intrusives ranging from granite to basic varieties represented by the gabbros. They are lithologically analogous to the prevailing rock types that are described in connection with the mining districts of Clinton and Essex counties and in some cases no doubt can be correlated as parts of the same geologic formations, though it is not to be inferred that they are strictly equivalent as to time. All are older than the most ancient of the fossiliferous strata in the region, the Potsdam sandstone, and underlie the latter unconformably.

The Grenville limestones and their associated schists (called the Oswegatchie series by Professor Smyth) are relatively less important in the interior than in the western part of St Lawrence county. A belt of these rocks traverses the town of Pitcairn and extends across the line into Jefferson county, with a length of 15 miles from northeast to southwest. There are good exposures of the limestone at Harrisville and on the east side of Bonaparte lake, in the middle portion of the belt. This is the most easterly of the larger areas, as elsewhere in the interior the rocks occur in isolated patches of no great size. The limestone is always thoroughly crystalline; the schists belong to the hornblendic, micaceous, pyroxenic or quartzose types so characteristic of the Grenville series throughout the Adirondacks.

Among the gneisses which occupy most of the area in the vicinity of the mines, there is great variety. Some are closely related to the igneous rocks and have been demonstrated to be in part simply gneissoid phases of the latter. On the south side of the limestone belt referred to above, syenitic gneiss grading into massive syenite is exposed in force underlying an area estimated at 75 square miles. It is clearly igneous and later than the limestone. In association with it occurs a more acid hornblende gneiss which seems to belong to the same intrusive mass, since there is a gradual transition across the contact. On the north side of the limestone belt,

[1] For the results of Professor Smyth's work, consult the annual reports of the New York State Museum for 1893, 1895, 1897, 1898 and 1899.

north and east of Harrisville, recognizable gabbro outcrops have been found. These rocks, it may be noted, are comparatively rare, in contrast with their wide distribution elsewhere in the Adirondacks.

A prominent member of the gneiss series is a coarse reddish hornblende rock which has the composition of granite. It is abundant in the region east of Harrisville, particularly between Benson Mines and Cranberry lake and the section northward. Its affinities are with the igneous rocks, as indicated by field evidence in places, though further investigation is needed to prove that the gneiss is of uniform character and derivation.

Certain representatives of the gneisses are undoubted metamorphosed sediments, yet contain no included bands of limestone. Their sedimentary origin is traced by their mineralogical and textural peculiarities. They have a variable composition, light colored quartzose varieties alternating across the strike with dark varieties in which there is a considerable proportion of hornblende, mica or pyroxene. Garnet is a frequent constituent and pyrite is seldom wanting. Sillimanite also appears, but rarely in crystals sufficiently large to be distinguished without the aid of the microscope. The constituents have a granular habit, without the definite arrangement or texture which obtains in igneous rocks. These gneisses are to be classed as members of the Grenville series. They are very much like the hornblende and mica gneisses that occur over large areas in the eastern Adirondacks and which have been assigned to the base of the Grenville.

Description of mines

Benson mines. The deposits are in the town of Clifton, on the north side of Little river. Benson Mines is a hamlet and a railroad station, 43 miles east of Carthage. The valley lies at an elevation of about 1600 feet, while the limiting ridges are somewhat more than 2000 feet.

In his report on the Second District,[1] Emmons mentions the occurrence of magnetite bodies on the Oswegatchie river near the crossing of the former highway known as the Albany road. From the accompanying description it is evident that the present Benson mines are referred to; and the stream now known as Little river was probably designated on the old maps as the Oswegatchie of which it is a tributary. Emmons states that a considerable quan-

[1] Survey of the Second Geological District. 1842. p. 347.

tity of ore had been taken from the locality and transported to Canton for reduction.

Systematic mining was not started until the extension of the railroad into the region in 1889. A mill was then erected on the property for the purpose of concentrating the ore into a commercial material, and was run until 1893 when, owing to a depression in the iron trade, the operations became unprofitable. Mining was again resumed in 1900, but only for a short period.

The total production subsequent to 1889 has been estimated at 370,000 tons crude ore, or 150,000 tons mill concentrates of above 60 per cent iron. The mines were developed and worked by the Magnetic Iron Ore Co., who have recently been succeeded by the Benson Mines Co. Mining operations were resumed in the fall of 1907.

Geology and occurrence of ore. In their general nature the deposits are much like those at Lyon Mountain. They consist of bands of gneiss charged with magnetite which is mainly disseminated more or less evenly through the rock mass. The bands are directed by the prevailing foliation so as to conform to it in strike and also probably in dip. A series of these parallel and coalescing bands constitutes the ore belt in which the mines have been opened.

The country gneiss has the appearance of a metamorphosed sediment and the writer feels little hesitation in placing it in the Grenville formation, though the absence of any limestone restricts the evidence bearing upon its origin to lithologic considerations. Observed in the field it exhibits no constancy of character from place to place. It is variously a hornblende, biotite or pyroxene gneiss and again may be destitute of dark minerals except magnetite. The different types occur as interpositions rapidly changing from one to another across the dip. The foliation, which is not particularly well developed, seems to follow consistently the division planes between them. Pyritic impregnations lend a rusty stain to the surface in places. In the composition of the gneiss, feldspar, quartz and the ferromagnesian minerals above mentioned partake most largely. The feldspar is orthoclase with subordinate oligoclase and microcline. Scapolite, sillimanite, zircon, apatite and garnet are among the less common constituents.

The principal ore belt lies near the base of a ridge which rises north of the railroad. The ridge has a northeasterly trend with a gradual slope in the lower part where it falls away toward the river. At the locality of the open pits by the mill, the surface

is only from 50 to 100 feet above the river and it continues practically at the same level for a distance of 500 feet or so to the north.

The strike of the ore is here about n. 60° e. West of the pits the deposit follows that course nearly in a straight line for a distance of 1000 feet; it then turns quite abruptly toward the northwest, at nearly right angles to its former direction, and ascends the ridge. It apparently dies out or disappears in a swampy tract about a mile west of the railroad station. The outcrop is concealed over considerable intervals, but the magnetic determinations serve to fix its course with reasonable accuracy. North of the pit the continuation of the ore can be traced across the highway and brook. There is some uncertainty as to the further extent of the deposit owing to the heavy covering of drift, though the magnetic surveys indicate that it wedges out or grades into the country rock within a few hundred feet north of the brook. The strike in this part is nearly due north.

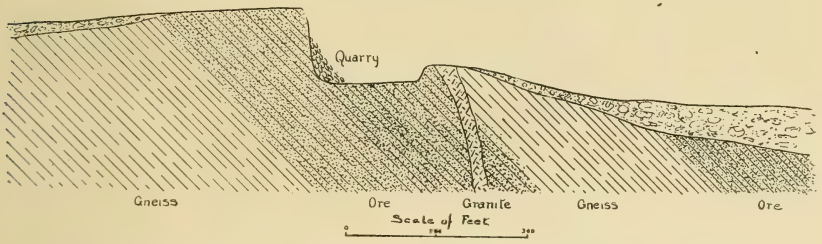


Fig. 22 Benson Mines. Section across the ore bodies, near middle of quarry

Observations of the dip of the ore and inclosing strata show a monoclinal arrangement for the central and northern parts of the ore belt. The gneiss on top of the ridge lies nearly flat. Passing across the strike to the southeast the dip increases gradually until at the pits it is about 45° southeast. This inclination is maintained with little variation for 1000 feet along the outcrop of the ore to the southwest. At the bend or fold in the deposit where it swings toward the northwest, the dip is 60° southeast. Beyond the bend there is a flattening of the dip, and over the remaining distance in which the ore can be traced the outcrops show the strata lying nearly horizontal or slightly inclined to the northwest. The change in the dip takes place within an interval of 100 feet and would seem to indicate a structural break, though there has been no discernible displacement of the ore by faulting.

Besides the deposit described, there are indications of another

belt of ore to the north of Benson Mines that has never been explored or developed. The belt lies to the east of the first and higher up in the gneiss. It begins on the south, according to magnetic readings, nearly opposite the north end of the pits and on line with the railroad. It extends in a northerly course toward Newton Falls in which direction it has been traced for nearly 2 miles. There is little evidence to be obtained from outcrops, the drift being heavy, so that the size and character of the deposit are practically unknown. The magnetic attractions are reported to be fully as strong and continuous as those recorded over the belt that has been mined. The cross-section, herewith, is intended to show the relation of the deposits [fig. 22].

Description of workings. In the open pit, which represents the result of the former productive operations, the deposit has been quarried from the south or hanging side back into the ridge for a horizontal distance of 150 feet. The working face, at first but a few feet above the floor, increases across the dip and is now 50 feet high on the average. The bounds of the deposit have not been reached either on the hanging or foot-wall side. An additional width of fully 50 feet can be gained on the foot-wall, where the ore has been uncovered by stripping of the soil and glacial materials and it is not improbable that the workings may be carried still farther west before reaching the limit of pay ore. The width of the ore, it may be noted, is determined only by arbitrary standards of what can be mined and treated at a profit. There is every gradation between the country rock and the ore, so far as relates to the proportion of magnetite present. Along its course the deposit has been worked for a distance of nearly 1200 feet, the length of the pit from east to west. At the west end there is a face from 15 to 40 feet high in which the ore appears to be of average grade. Its continuation in this direction is assured for several hundred feet by the outcrops and the test pits excavated through the light overburden of glacial material. At a point 1000 feet west of the workings, a ledge is exposed for 100 feet which is reported to average about 40 per cent iron. On the east end the deposit runs out into the valley and has not been uncovered.

The exploration of the deposit in depth, below the level of the open pit, has been limited to a few borings that were made several years ago. Four of these borings are on record, of which the deepest is 180 feet vertically from the outcrop. It encountered ore all the way with a range of from 32 to 44 per cent iron, as shown by assay of 10 samples taken at succeeding intervals. The holes are said to

Benson mines. Open pit with face of ore

have been put down somewhere in the vicinity of the pit, though their exact location is not now known.

Within the limits of the exposures the ore exhibits much uniformity. This feature is naturally of prime importance to the economic working of a low grade body such as the present one. Occasional stringers of pegmatite and a fine reddish granite are encountered which carry little magnetite, but they have not proved a serious obstacle to exploitation. In the previous working, the deposit was quarried without leaving any waste and the entire output was sent to the mill.

The deposit has apparently undergone little disturbance in the way of faulting. A slip seems to have taken place near the hanging wall at the pit entrance parallel to the strike of the ore body, but it is probably slight, as there is ore showing on both sides with no marked brecciation. A thin dike has been intruded along the fault fissure. The ore next to the fault has been partially altered to martite.

Character of the ore. The minerals accompanying the magnetite are quartz, feldspar, garnet, biotite, pyrite and apatite. Quartz and feldspar constitute the matrix for the most part, while the magnetite functions as a binding material. The feldspar is mainly the orthoclase variety. The pyrite and garnet are intimately associated with the magnetite, the former occurring as small included grains and the latter as rims on the borders of the magnetite particles. From the manner in which the magnetite and pyrite are intergrown, it is evident that they have been deposited at the same time. The garnet, however, is a later crystallization formed by a reaction between the magnetite and the feldspar in which the chemical constituents of both have been combined. It is a red garnet and responds strongly to tests for manganese. As a rule the ore is rather fine grained, though coarser in this respect than the country gneiss. Like the latter it shows a gneissoid texture. Occasionally the magnetite is segregated in thin bands interleaved with the silicates.

The following analyses give details as to the chemical composition of the ore. No. 1 is the result obtained from a sample of the ore exposed in the present workings, the sample being made up of numerous specimens selected so as to give an average for the entire face of the quarry. The sample was gathered and analyzed by E. Touceda. No. 2 represents a sample of concentrates, an average of 132 cars; and No. 3 a sample of concentrates recently taken from a small lot in the storage bin at the mines.

	1	2	3
Fe_3O_4	49.43	88.08	85.94
FeS_2	1.61	.864	.....
SiO_2	33.32	5.97	5.91
TiO_2	1.07	.....	1.06
P_2O_5	.43	.086	.11
Al_2O_3	6.92	2.26	3.63
MnO	.32	2.04	.43
CaO	1.42	.28	.68
MgO	.91	.18	.08
K_2O	2.77	.....	.87
Na_2O	.58	.....	
CO_2	.68	.....	.42
H_2O	.35	.....	.42
	99.81	99.76	99.55
Iron	36.56	64.18	62.24
Phosphorus	.186	.037	.048
Sulfur	.86	.461	.37
Manganese	.246	.158	.33
Titanium	.64	.....	.64

It will be observed that the ore in its crude state is not of Bessemer grade. The concentration, however, eliminates sufficient phosphorus so that the product can be used for Bessemer pig. As a result of the milling operations it was found that the quantity of phosphorus passing into the concentrates could be regulated to some extent by the crushing. With fine crushing the apatite which carries the phosphorus is mostly released and under the magnetic treatment goes into the tailings.

Of the shipments made in the first period of operations, a large part averaged over 60 per cent iron with less than .03 phosphorus. The coarser concentrates carried as high as .47 per cent phosphorus. In the last campaign in 1900 and 1901, the product of some 70,000 tons averaged from 63 to 64 per cent iron, about .037 per cent phosphorus and .46 per cent sulfur. The concentrates were used by Pennsylvania furnaces for Bessemer and foundry irons.

The following analysis is of interest as showing the chemical constituents of the gangue, which may be considered closely analogous in all respects to the country rock. It was made from a sample of mill tailings produced during the regular course of operations.

SiO_2	67.18
Al_2O_3	17.97
Fe_2O_3	1.02
FeO	6.13
CaO	1.84
MgO	1.50
Na_2O	.44
K_2O	1.12
P_2O_5	.36
MnO	.30
S	2.06
	99.92

Jayville mines. Jayville is 14 miles west of Benson Mines and 29 miles by rail from Carthage. With the cessation of mining in 1888 the buildings and machinery were removed and the place has since been practically abandoned, leaving only the waste heaps and pits as witness to the former activity. The mines were last operated by the Magnetic Iron Ore Co., who instituted extensive developments in 1886. The existence of the larger deposits at Benson Mines soon led the company, however, to give up the undertaking in favor of that locality. The mines are credited by Smock with an output of 25,000 tons during the last period of operation.

The ore occurrence presents a phase quite dissimilar from that at Benson Mines and more like the magnetite deposits on the east side of the Adirondacks. There are innumerable shoots, lenses and irregular bunches in which the magnetite is found showing sharp boundaries in contact with the wall rock. The latter is for the most part a hornblende-biotite gneiss of sedimentary appearance. The horizon of the ore lies close to the contact of the gneiss with a red pegmatitic hornblende granite. Outcrops of the granite occur to the north and east within short distances where they break through and cut off the gneiss area in such a way that their intrusive character is plainly evidenced. In some of the openings the granite can be seen in immediate contact with the ore.

The openings are on the northeastern and northwestern slopes of a low ridge of the gneiss that rises just west of the railroad. The pits nearest the station are Hart no. 1 and no. 2, of which the first is said to be 300 feet deep following a shoot 20 feet wide and 10 feet thick. Hart no. 2 is much shallower. At the northeastern end of the ridge where it curves to the west are the pits called New

York no. 1 and no. 2, both of inconsiderable depth. Benson no. 1 farther to the west is reported by Smock to have a depth of 350 feet on the incline; of its two levels the upper is about 25 feet long and the lower driven at a point 60 feet from the bottom of the slope runs off in a southerly direction for 160 feet and then north 60 feet. This pit supplied most of the shipping ore. Between Benson no. 1 and no. 2 an adit has been excavated into the hill on a lead which in the interior develops into a lens some 60 or 70 feet long and 20 feet wide. The Fuller and Essler pits are located at the extreme west, the former being opened on a pod of ore 50 feet wide, dipping 45° west.

The distribution of the ore in disconnected bodies which pitch and strike in all directions has probably resulted from the intrusion of the granite. The bodies occupy approximately the same horizon and have the aspect of an originally continuous band which has been disrupted and faulted. The intrusion has exercised also a metamorphic influence upon the deposits shown by the abundance of garnet and hornblende that often replace the magnetite almost completely. Well developed titanite crystals of unusual size are found in the contact zone.

The analysis below taken from Putnam's report, gives the composition of the Jayville ore. It was made from a sample of 500 tons mined in 1880 and shipped to the furnace at Alpine. It represents the selected lump ore, sufficiently high in iron to be used without concentration.

Iron	56.72
Titanium	nil
Phosphorus	.009

Mines on Vrooman ridge, Fine. This locality is 4 miles northwest of Oswegatchie on the Carthage and Adirondack Railroad, in the town of Fine. Vrooman ridge is the first of the elevations bordering the Oswegatchie river valley on the south.

From a cursory examination of outcrops it appears that the ridge is mainly composed of reddish hornblende gneiss, with one or more included bands of dark pyritic schists and limestone which are doubtless altered sediments. The ore deposits are associated with the latter. They have been explored by shallow pits; apparently no active mining has been undertaken. So far as could be determined by surface observations, there are two parallel veins that strike about north and dip 50° or so to the west. On

the eastern vein, which seems to be the principal one, two pits have been sunk, 330 feet apart, to a depth of about 30 feet. The indicated width is from 8 to 12 feet. The hornblende schist forming the walls is streaked by limestone in which phlogopite, titanite and coccolite are abundantly distributed in small crystals. Hornblende and pyrite are mixed with the magnetite and much of the ore is lean. The two pits on the western vein indicate a width for the ore of 5 feet. According to a report rendered by Mr George D. Grannis, who superintended the exploratory operations, the deposits have been prospected to some extent by diamond drilling. One hole was put down on the north pit of the eastern vein to a depth of 85 feet, all in ore. A second boring was started 100 feet west of the pit for the purpose of intersecting the body at an angle and encountered two veins, one 4 feet and the other 10 feet wide separated by 4 feet of rock. These may represent the western vein above mentioned, here split by a horse of the wall rock. Another hole in line with the second but farther south showed the two veins to have a thickness of 4 feet and 6 feet respectively with 6 feet of rock between them. The following analyses have been copied from a report on the property made by Mr Spencer B. Newberry.

	1	2	3
Iron	71.12	61.46	62.02
Silica	.860	.....	6.36
Titanium	tr.	nil	.....
Sulfur	.005	.025	.03
Phosphorus	.049	.009	.024
Manganese	tr.	.....	.....
Lime	.051	.....	.....
Magnesia	tr.	.....	.....

Clifton Mines. The Clifton deposits are situated about 10 miles north of Benson Mines, in an unsettled forested district that is somewhat difficult of access. They were opened over 50 years ago but have not been worked recently. A charcoal furnace was built at Clarksboro by the falls of the Grasse river, 3 miles distant from the mines, and was run for some time on the ore. In 1868 the Clifton Mining Co., which then owned the property, erected a plant for manufacturing steel by a direct process, a venture that soon proved a failure. The mines were at one time connected with the Rome, Watertown & Ogdensburg Railroad near DeKalb Junction by a 20-mile wooden railway.

In approaching the mines from Oswegatchie, the highway after leaving the Oswegatchie river at Fine passes over a belt of hornblendic and micaceous gneisses and schists that continues for a mile or more and is then succeeded by a red granitic gneiss with porphyritic feldspars. This rock prevails in most of the exposures as far as Monterey. Between that locality and the Clifton mines the granitic gneiss gives way to a belt of schists and limestones having a northeast-southwest trend parallel to their general strike. These are the predominant rocks in the vicinity of the ore bodies. They seem to have been somewhat broken and disturbed as they show sudden changes in dip; the inclination, however, in most cases is toward the southeast at angles of 15° to 45°.

The openings are located on the sides and summit of a hill rising 100 feet or a little more above the site of the steel works in the adjoining valley. The principal working is an open cut on the summit which exposes a vein 20 feet wide for a distance of about 500 feet. This is known as the Dodge vein. The immediate wall rock is a hornblende schist. Bands and fragments of the schist interleave the ore, and on the borders the two are intimately mixed. The hornblende gangue carrying the magnetite makes an exceedingly tough material. On the northeast side of the hill the vein has been tapped by an adit and in the walls crystalline limestone is exposed in what seems to be an included band about 5 feet thick. The southwest continuation of the vein has been explored by a shaft that follows the dip for 30 feet, showing about 20 feet of ore all the way. East of this deposit and higher up in the schists is the St Lawrence vein, 8 feet thick, that has been explored by open cutting and by an incline said to be 100 feet deep. The ore from it is very sulfurous, in places almost solid pyrite and pyrrhotite. A third vein is known to underlie the Dodge vein, but its width and character have not been determined.

The ore found in the different openings varies from a coarse and nearly pure magnetite to a fine grained mixture of disseminated magnetite and the minerals of the wall rock which are chiefly hornblende, biotite, garnet and quartz. Pyrite is less in evidence in the middle of the veins than on the borders. The ore was subjected to heap roasting before it was smelted to reduce the sulfur. The analyses that follow are quoted from a paper on the Clifton mines by Professor Silliman.[1]

[1]Am. Inst. Min. Eng. Trans. 1871–72. 1:364.

	1	2
Fe_3O_4	79.29	80.91
SiO_2	8.32	8.77
S	.35	.08
P_2O_5	.32	.03
Al_2O_3	3.45	.....
MnO	.35	.....
CaO	4.46	.....
MgO	3.09	.....
H_2O	.51	.....
	100.14	.....
Iron	57.42	58.59
Phosphorus	.14	.01

The analyses were made from crude ore, but the quantity o sulfur shown is rather low for the run of mine, specially in the second sample which also contains very little phosphorus. It is of interest in this connection to quote Professor Silliman's analyses of the pig iron made from the Clifton ores in the old Clarksboro furnace. The ore was fluxed with an impure limestone containing a considerable proportion of silica.

	Open grain gray pig	Close grain gray pig
Carbon	3.94	3.30
Silicon	2.21	4.48
Manganese	.11	.12
Sulfur	.04	.11
Phosphorus	.22	.15
Iron and undet	93.48	91.84
	100.00	100.00

In the same vicinity occur two other deposits that were found by the early prospectors and were known as the Tooley Lake and Sheridan veins. They outcrop in a swampy tract, 7 and 2½ miles distant respectively from the Clifton mines. The localities were not visited by the writer. In character the ores are similar to those just described, as shown by the following analyses, no. 1 being from a sample of the Tooley Lake vein and no. 2 of the Sheridan vein.

	[1]	[2]
Iron	54.32	57.81
Silica	13.34	8.55
Sulfur	.08	.41
Phosphorus	.01	tr.
Manganese	.29	.50

Parish ore body. This deposit is 8 miles east of Monterey, on Tracy pond outlet, Clifton township. Its outcrop has been uncovered by trenching for a short distance, but it has not been explored in depth. The width shown is about 8 feet. The deposit appears to have a steep dip so that the actual width is probably near the figure given. The wall rock is fine grained grayish gneiss, while nearby reddish granitic gneiss is exposed, and within a mile distant an area of crystalline limestone and sedimentary schists. The magnetite is mixed with the minerals of the gray gneiss and with red garnet, yet is fairly rich. It has a coarse granular texture. It contains no pyrite so far as observed. It is reported that a line of magnetic attraction can be traced for 800 feet north and south of the tract along the course of the vein. The analysis below is from a sample of the ore.

Iron	50.3
Phosphorus	.58

SALISBURY MINE, HERKIMER COUNTY

This mine is in the town of Salisbury, 5 miles north of Dolgeville, the present terminus of the branch railroad running north from Little Falls. It is the only magnetite mine in this section of the Adirondacks that has been actively worked.

The deposit apparently was discovered about 1840. Vanuxem who has given a brief description of it states that a small amount of ore had been taken out at the time of making his report.[1] It is probable that the old pits located along the outcrop of the ore body date from this period. The quantity of ore mined during the early operations is not a matter of record though the size of the openings leads one to infer that it did not exceed a few thousand tons.

Geological relations. The locality lies within the Little Falls topographic sheet, the geology of which has been mapped and described by H. P. Cushing.[2]

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[1] Fourth Annual Report of the Geological Survey of the Third District, 1840.

[2] Geology of the Vicinity of Little Falls. N. Y. State Mus. Bul. 77. 1905.

The immediate area about the mine is occupied by the Adirondack Precambrics. These rocks extend southward as a belt of gradually diminishing width to within 4 miles of Little Falls, passing at the borders beneath the Lower Siluric strata (Beekmantown, Trenton and Lorraine) which spread over the region to the south. There is a large outlier of Precambric syenite at Little Falls and smaller ones of the same rock at Middleville, northwest of Little Falls, and at a point about half way between the latter locality and the southern end of the main area. The contact between the Precambric and Paleozoic strata on the east side of the belt is marked by a heavy fault which begins south of the Mohawk river and runs northeast passing about 2 miles east of the mine.

The principal representative of the Precambric rocks is syenite, a greenish augite-bearing variety that is identical mineralogically with the great syenite masses in the central Adirondacks. It has a gneissoid appearance in most cases and shows strong crushing effects in the granulation of the feldspar. Occasionally uncrushed remnants of feldspar may be observed surrounded by granular material, like an augen gneiss. The syenite is exposed over most of the area north of Salisbury Center.

The Grenville series of gneisses and schists form the southern extension of the Precambric belt south of Salisbury Center and is exposed north of the mine in two areas which are bordered by the syenite. It consists of light colored quartzose gneisses interbanded with darker hornblendic or micaceous varieties. Crystalline limestone, usually a prominent member of the series, apparently has a very limited development within the area; the only outcrop that has been recorded is one observed by the writer at a point a little north of Salisbury Center. The gneisses are believed by Cushing to represent original sandstones and shales.

A reddish gneiss comprised mainly of quartz and alkali feldspar occurs at a few places in association with the syenite and rocks of the Grenville series. Its field relations as well as its composition suggest an original granite that is probably intrusive in the sedimentary gneisses. Cushing mentions also the occurrence of black gneisses, containing hornblende and biotite and occasionally pyroxene, and gray gneisses of granitic composition which are regarded as igneous derivatives.

Ore bodies. The deposit which has been principally worked extends nearly east and west along the highway 2½ miles north of Salisbury Center. It consists of an elongated zone made up of magnetite in one or more bands intercalated between layers of

magnetite-bearing rock. The thickness of the zone as shown in the workings ranges up to an extreme of 12 or 14 feet in width. The bands of rich ore vary from mere films to 2 or 3 feet. The ore body can be traced along the strike by outcrop and dip-needle readings for fully a mile.

A second smaller body occurs about a mile south of the first. It has been opened by a short adit at one point. The strike is parallel with the main deposit, but the dip is toward the north at a low angle, while the latter has a high dip southward. An area of granitic gneiss intervenes between the two deposits.

The wall rock at both localities is gneissoid syenite. Of the ore association, Cushing[1] has given the following account:

> Inclosing the ore and grading into it, is a very basic gneiss composed of hornblende, magnetite, augite, feldspar and quartz, the black minerals constituting 75 per cent of the rock. Hornblende is much the most abundant of these. About equal amounts of quartz and feldspar are present, the feldspar being part oligoclase and part orthoclase.
>
> So far as can be judged from specimens obtained from the dumps, this gneiss grades rapidly into a more feldspathic hornblende gneiss, and the latter into syenite gneiss, at first basic but rapidly becoming more acid.
>
> The gradation between ore and country rock is very noticeable; no well defined walls exist, but there is a shading off by imperceptible stages from one to the other.

The workings. The mining developments which have been carried on during the last two or three years by the Salisbury Steel & Iron Co. have been concentrated on the western portion of the deposit in proximity to the old pits. A vertical shaft has been sunk a short distance north of the main pit. It has been carried down about 200 feet. At a depth of 100 feet a drift has been extended easterly along the body, while a second level with drifts to the east and west has been opened at 150 feet. The workings are about 14 feet wide near the shaft on the second level, diminishing to 3 or 4 feet at either end.

Some prospecting has been done at points east of the shaft, the farthest being about 4000 feet away. The deposit appears to be much thinner in this part.

Character of the ore. The ore consists of granular and massive magnetite, the former being a mixture of magnetite and the minerals of the wall rock and the latter a nearly pure magnetite of very dense

[1] *Op. cit.* p. 91.

structure. The granular ore has a fine texture; the particles of magnetite are intimately intermingled with pyroxene, hornblende, quartz and feldspar. Veinlets of jasper and white quartz are quite common. Pyrite occurs in noticeable quantity on the east end of the zone, but is not much in evidence elsewhere. When examined under the microscope, sections of the rich ore show inclusions of augite, quartz and apatite, but the proportion of these minerals to the whole mass is small and the material would be classed as shipping grade. The lean ore would require concentration. An analysis furnished by the Salisbury Steel & Iron Co. shows the following composition:

Fe_3O_4	86.99
SiO_2	6.39
S	.034
P_2O_5	1.36
Al_2O_3	1.14
MnO	.46
CaO	2.83
Mg O	.65
	99.854
Iron	62.99
Phosphorus	.52

Part III

TITANIFEROUS MAGNETITES

Under this class are included the magnetic ores of the Adirondacks that carry titanium as an essential ingredient. While the percentage of this element fluctuates within rather wide limits as shown by analysis of specimens taken from different localities, the minimum is always above the proportions encountered in the magnetites previously described. In the general run it amounts to at least 8 or 9 per cent (as TiO_2) and will average perhaps 15 per cent in the majority of the deposits. It is due solely to the titanium content that the ores have not been more actively exploited. Except for the early work at Lake Sanford, of which further mention is made on a subsequent page of this report, there has been no active mining of the deposits in the region, and till recently little interest has been shown generally in the matter of commercial utilization of titaniferous ores.

The Adirondack region is a familiar one in the literature relating to these ores. The descriptions of Emmons[1] who was the first to draw attention to the large ore bodies of Lake Sanford, the metallurgical experiments of Rossi[2] in connection with the same bodies, and more recently the detailed accounts by Kemp[3] covering practically the entire series of occurrences may be specially noted. The investigation of the geological features of the Adirondack ores has been carried out by Professor Kemp in a manner that leaves little to be added, and his descriptions and conclusions have been closely followed in the present work.

Distribution of the ores

The distribution of the titaniferous magnetites is conditioned primarily by the occurrence of the gabbro-anorthosite intrusions. As has been previously noted, the principal area of these rocks is

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[1] Survey of the Second Geological District, 1842.

[2] Titaniferous Ores in the Blast Furnace. Am. Inst. Min. Eng. Trans. 1892–93. 21:832. Also article in the Iron Age, Feb. 6 and 20, 1896.

[3] Preliminary Report on the Geology of Essex County. N. Y. State Mus. 49th An. Rep't. v. 2. 1898. The Geology of Moriah and Westport Townships. N. Y. State Mus. Bul. 14. 1895. The paper "Titaniferous Ores of the Adirondacks," published in U. S. Geol. Sur. 19th An. Rep't. pt III, 1899, contains much additional matter relating to the origin and chemical nature of the ores.

in Essex and southern Franklin counties and consists of a connected mass which spreads over a surface of some 1200 square miles. There are smaller outlying intrusions in Clinton and Warren counties and in the western Adirondack region. The greater number of deposits are found within the bordering portions of the main anorthosite area in the townships of Westport, Elizabethtown and Newcomb, Essex co. In the central part no large bodies are known. A deposit near Port Leyden, Lewis co., is the only occurrence outside of the main area that has been the object of exploitation.

General geological relations and origin of the deposits

The titaniferous deposits constitute a well marked type of ore occurrence that is quite widely distributed in this and foreign countries. They are known to be of considerable extent in Minnesota, Wyoming and Colorado, in the Provinces of Ontario and Quebec, and in Sweden, Norway and Brazil. The Taberg deposit in Sweden was mined for a number of years and the ore used for the manufacture of iron. The various localities for titaniferous magnetites have been described briefly in a paper by Professor Kemp.[1] The occurrences throughout show a remarkable degree of uniformity in the essential features of their geological surroundings and composition of the ores.

With a single exception the country rocks of the Adirondack deposits, as is generally the case elsewhere, are members of the gabbro family. The prevailing rock in the Adirondack region is the variety known as anorthosite, the predominant constituent of which is a basic plagioclase feldspar, usually labradorite. The rock is the first of a series of related intrusions in the region that were derived apparently from a common magma. Gabbro in the restricted sense, syenite and probably granite are represented among the later intrusions derived from the same source. Most of the deposits are found within dikes and masses of gabbro which occur at intervals throughout the anorthosite area. Some of the large bodies at Lake Sanford, however, are inclosed directly by the anorthosite.

The general characters of the gabbros and anorthosites have already been set forth in the part of this report relating to Adirondack geology. The following analyses taken from Professor Kemp's paper give details as to the chemical composition of typ-

[1] A Brief Review of the Titaniferous Magnetites. Columbia Univ. Sch. of Mines Quarterly, July 1899.

ical examples. No. 1 relates to the gabbro at the Split Rock mine; No. 2 to gabbro at Lincoln pond; and No. 3 to anorthosite from Mt Marcy.

	1	2	3
SiO_2	47.88	44.77	54.47
TiO_2	1.20	5.26	.....
Cr_2O_3	tr.	.....	.....
Al_2O_3	18.90	12.46	26.45
Fe_2O_3	1.39	4.63	1.30
FeO	10.45	12.99	.67
NiO.CoO	.02	tr.	.....
MnO	.16	.17	.....
CaO	8.36	10.20	10.80
SrO	tr.	.....	.....
BaO	tr.	.....	.....
MgO	7.10	5.34	.69
K_2O	.81	.95	.92
Na_2O	2.75	2.47	4.37
Li_2O	tr.	.....	.....
H_2O	.61	.60	.53
P_2O_5	.20	.28	.....
V_2O_5	tr.	.....	.....
CO_2	.12	.37	.....
S	.07	.26	.....
	100.02	100.75	100.20

The Port Leyden ore body on the west side of the Adirondacks seems to be an anomaly among the titaniferous occurrences. The wall rock is not a basic variety belonging to the gabbro-anorthosite family, but a quartz gneiss with potash feldspars and a small quantity of ferromagnesian minerals. Yet it is not unlikely that the deposits may represent only an aberrant type of the ordinary occurrences. If the country rock is igneous, as is believed, it probably belongs to the general series of intrusives that originated from a common parent mass. The ultimate source of the iron minerals may thus have been the same as those of the gabbros.

In the relations they bear to the inclosing rocks, the ores are sharply differentiated from those of the nontitaniferous class which occur in the sedimentary gneisses and schists. They are themselves only a phase or development of the igneous magma from which the walls have been derived — that is they are rocks

differing in composition but of the same genesis as the anorthosite and gabbro. The magnetite and ilmenite of which they are aggregates exist in the country rocks as accessory constituents. A concentration that took place probably during the cooling of the magma effected the segregation of the heavy minerals into compact masses forming ore bodies of variable size and richness. This view of the relation of the Adirondack ores has been clearly brought out by Professor Kemp[1] in the following terms:

In the preceding pages the point of view has been consistently maintained that the ore bodies are integral portions of the igneous rocks in which they occur and are merely local enrichments of the mass with unusual amounts of one of its normal constituent minerals. This has not been done with the purpose of advocating one conception of the relations of the ore and wall rock to the exclusion of others, but because the observed phenomena admit of no other reasonable interpretation. There is no evidence of the replacement of preexisting material by an entering foreign substance, nor of faults and vein formation, nor of crushed zones different from the neighboring walls; nor are the ores at the contacts of intrusions with country rock. On the contrary, the masses of ore, of irregular shape, are far within the intrusions, and especially in the gabbros they vary from rich titaniferous iron oxide, through leaner and leaner examples, until normal gabbro is reached. No minerals or elements occur in notable amounts in the ores which are not characteristic components of the wall rock. The difference between ore and rock is one of degree and not of kind. At Calamity brook the ore itself forms a series of dikes in country rock of a different kind.

The causes acting to produce such a concentration or magmatic differentiation are little understood. Gravity, convection currents, magnetism, and diffusion consequent upon variation in the rate of cooling are some of the agencies that have been appealed to by the leading investigators to account for the accumulation of the deposits.

It is of interest to note that the igneous theory of derivation for these ores which has come into prominence in recent years and is now generally accepted by geologists the world over, was foreshadowed by Professor Emmons in his report on the Adirondack region for 1842. The ore occurrences at Lake Sanford were designated by him as "masses," to distinguish them from the "veins" or tabular bodies occurring in the gneisses, and they are described as of contemporaneous origin with the inclosing rocks which he recognized to be igneous.

[1] Titaniferous Iron Ores of the Adirondacks, p. 417.

Shape of the ore bodies

The form assumed by the ore bodies is not always apparent from the field evidence. It is only the smaller ones as a rule that are well exposed in outcrop. The large bodies have nowhere been uncovered or explored sufficiently to afford an idea as to their precise outlines. The smaller bodies, with a few exceptions found at Lake Sanford, occur in gabbro which generally appears in dikes cutting the anorthosite, and partake of the usual tabular form with the longer axis parallel to the strike of the dikes. They show gradation at the edges into the normal gabbro and their materials have no doubt come up with it from a common reservoir below. As to the deposits inclosed by the anorthosite, it is not conclusive whether the ores have separated in place from the surrounding rock, or whether they represent later concentrations in the interior that have been intruded into the anorthosite after its partial solidification. In the former case we should expect the bodies to be quite irregular, with no well defined walls, and to shade off at the borders with a gradual increase in the proportions of gangue material or rock. From the evidence at hand, the large bodies like the Lake Sanford would appear to be allied rather to that type than to the dike form.

Mineralogy of the magnetites

The titaniferous ores of the Adirondacks are essentially aggregates of magnetite and ilmenite. The richest ores contain little else than these minerals and show on analysis 60 per cent or slightly more of iron, the maximum percentage being somewhat below that of the high-grade nontitaniferous magnetites. From such pure aggregates there may be traced a continuous series of gradations, by the entering of gangue minerals in greater and greater proportions, to the limiting wall rocks which hold only subordinate amounts of magnetite and ilmenite.

The relations of the two iron minerals have received, hitherto, little attention. The presence of ilmenite has been inferred from the results of chemical analyses; its identification by the usual optical methods of petrography is difficult owing to its opacity and similarity of appearance to the magnetite with which it is intimately associated.

Ilmenite is not uniform in its composition and its chemical nature has been the source of considerable perplexity to mineralogists. The view that it is a metatitanate $Fe\ TiO_3$ has the support

of the most recent investigations; the work of Penfield and Foote[1] affords in fact quite convincing evidence of its validity. According to that formula it contains theoretically FeO, 46.75 per cent and TiO_2, 53.25 per cent. There is always some Fe_2O_3 present and usually more or less MgO. The latter replaces the FeO, while the former substitutes probably for the ilmenite molecule, since the close similarity in the structure and crystal form of hematite and ilmenite indicates that they are practically isomorphous. A general formula for ilmenite, accordingly, is $Fe\ TiO_3.n\ Fe_2O_3$.

The fact that the titaniferous ores are not homogeneous aggregates is sometimes apparent from a macroscopic examination. The magnetite may be recognized by its parting planes parallel to the octahedron, the grains always breaking with smooth surfaces. It is the most abundant constituent as a rule. In the intervals between the grains are particles of brighter metallic luster that show rough fracture. These are only slightly attracted by the magnet and when isolated prove to be ilmenite.

To bring out the physical relations of the minerals the method of preparing polished surfaces and etching with acid can be used to good advantage.[2] Some results obtained with Adirondack ores are shown herewith [pl. 14]. The photographs were taken directly with a camera in ordinary light, as the texture of the ores is sufficiently coarse to be revealed without the use of the microscope. It will be seen that there is a good contrast between the magnetite and ilmenite, the former being dulled and pitted by the solvent action of the acid, while the latter retains the brilliancy imparted to it by polishing unimpaired. From the etched surfaces a fairly close estimate of the richness of the ore may be formed by comparing the relative areas occupied by the ore and gangue minerals, though the latter do not appear distinctly in the photograph.

In the specimens that have been examined the magnetite and ilmenite are distinguishable without difficulty. There is a clear separation of the particles and no notable tendency toward intergrowth or inclusion on the part of either. The boundaries are sharp. Both minerals belong to the same order of crystallization, though the ilmenite seems to have begun to form somewhat earlier than

[1] Note Concerning the Composition of Ilmenite. Am. Jour. Sci. 154. ser. 4. 1897. p. 108.

[2] Pieces of the ore an inch or so in diameter are cut with a diamond saw or ground down to a comparatively smooth surface on a wheel such as is used for preparing rock sections. The surfaces are then polished with fine emery, finishing off with putty powder on cloth. The etching is performed by submersion in a 20 per cent HCl solution for half an hour.

the magnetite. The latter being commonly in excess constitutes the ground mass through which the ilmenite is more or less regularly distributed in grains of fairly even size.

A partial separation of the magnetite and ilmenite was obtained with the ore from the Sanford pit at Lake Sanford. A sample was crushed through a 40 mesh sieve and the magnetite removed with a small hand magnet. The results from chemical analysis of the crude ore (1), magnetite concentrate (2) and the ilmenite and other residual minerals (3) are given herewith. The analyses were made by E. W. Morley.

	1	2	3
Fe_2O_3	55.9	54.39	14.28
FeO	27.5	28.66	30.93
TiO_2	14	8.93	45.23

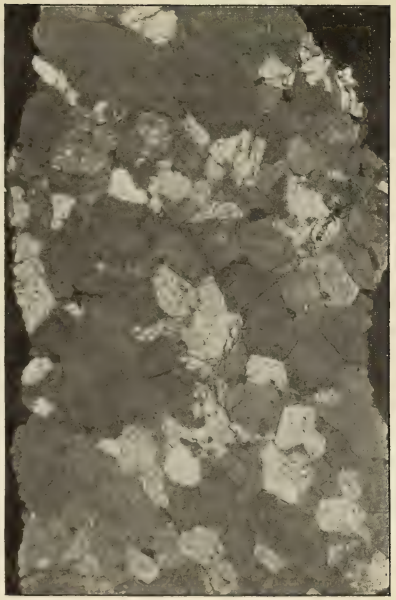
It will be observed that the magnetite concentrate still contains a considerable proportion of titanium, mostly due, no doubt, to the inclusion of particles of mixed character. By crushing still finer a cleaner separation may be made, as has been demonstrated for the same ore in recent experiments that are described on a subsequent page. The analyses are not reducible to simple terms of magnetite and ilmenite, and further work is needed before the chemical relations can be fully stated. It is quite likely that the magnetite itself carries a proportion of the titanium, in which case the entire removal of the latter would be impossible.

The remaining minerals found in the titaniferous ores include plagioclase, pyroxene, hornblende, biotite, olivine, garnet, pyrite, apatite, spinel and quartz. The plagioclase is usually labradorite or an allied variety. Both orthorhombic and monocline pyroxenes are represented. Olivine is rather rare in the Adirondack ores so far as observed. Pyrite is a fluctuating constituent, more abundant in the ores that are included by gabbro than in those found within anorthosite. Spinel has not been certainly identified, but its presence is strongly indicated by the analyses which show an excess of Al_2O_3 over the amounts required for the silicates. The analyses of concentrates on page 154 are suggestive also in that connection. Apatite is present in minute quantities only, and the ores are consequently low in phosphorus.

The order of crystallization of the minerals revealed by study of the etched surfaces is as follows: 1, silicates; 2, pyrite; 3, ilmenite and magnetite.

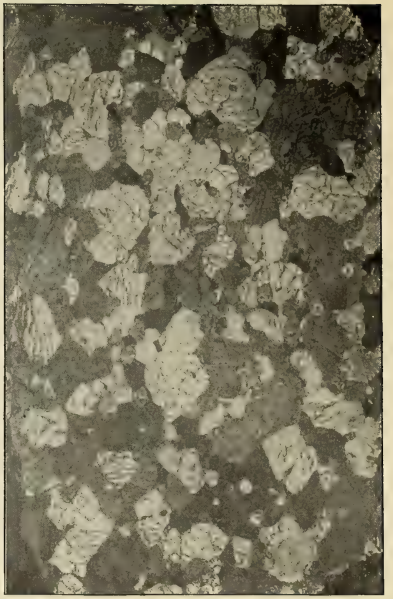
The order is thus the reverse of the normal one for igneous rocks in which the silicates predominate over the iron ores. The expla-

Plate 14



1

2



3

Etched surfaces of titaniferous ore. 1 Ore from Lake Sanford pit. 2 Same. 3 Ore from Moose mountain. Dark grains mostly magnetite with some pyrite and silicates; light particles are ilmenite

nation for this may be found possibly in the introduction of the magnetite and ilmenite after the congealing of the walls, the silicates representing material that was caught up during the progress of the iron magma toward the surface.

Commercial utilization of the titaniferous ores

The use of ores containing high percentages of titanium is generally regarded as impracticable under present furnace practice. They have been smelted, however, on a small scale in England and Sweden, as well as in the Adirondacks, under conditions approaching those of today, but the operations were short-lived and probably financially unsuccessful. It has been frequently suggested that the difficulties they present in the blast furnace might be overcome by adopting some changes either of furnace construction or of metallurgical process, but there has been, in the past, very little incentive to a practical investigation of the subject. The experiments by Rossi carried out in 1892 comprise about all that has been done along that line since the early work above mentioned.

The objection to the use of titaniferous ores in the blast furnace is based upon the infusibility of their slags. They yield a good quality of iron which contains only a slight trace of titanium. This element enters mostly into the slag, and with the employment of fluxes in ordinary proportions forms a viscous mass that adheres to the furnace walls and can not be readily withdrawn, while accumulations of the infusible nitro-cyanide of titanium also complicate the operation. Rossi sought to overcome the difficulty by proportioning the fluxes (quartz and limestone) so as to obtain compounds, mainly multiple-titanates, into which the titanium entered as a chemical constituent approximating the structure of the more fusible known titanates. By working with a small laboratory furnace, ores running as high as 20 per cent TiO_2 were reduced, with a production of pig iron and a fluid of slag. The experiments have not been repeated, so far as known, on a commercial scale.

It is not unlikely that a solution of the problem of dealing with the ores may be found by reducing the amount of titanium before entering the furnace. The small amount of the element found in most Adirondack magnetites now mined seems to have no noteworthy influence upon the smelting process. Furnaces have been run upon ores containing two or three per cent of titanium without serious trouble, and under special circumstances even larger percentages have been handled. There would thus seem to be some room for adjusting the difficulty, either by mixing the ores with others that are nontitaniferous or by concentration.

The Lake Sanford ores carry about 15 per cent TiO_2 on the average. They are probably the most regular in titanium content and highest in iron of the Adirondack ores. By employing them in mixture in the proportions of say 1 to 2 or 1 to 3, the titanium of the ore charge could be brought down to three per cent or less. Their low phosphorus and sulfur would make them specially valuable for that purpose.

Another feature which may promote the use of the ores from that locality is their amenability to concentration, whereby the titanium can be reduced by at least a third of the total, or to less than 6 per cent probably as maximum limit. To the courtesy of F. E. Bachman, General Manager of the Northern Iron Co., the writer is indebted for information concerning an experimental run made upon Lake Sanford ores at the Mineville magnetic concentrating plant within the past year. A 40 ton sample was passed through one of the mills and the concentrates showed the following percentages: Fe, 60.60 per cent; TiO_2, 9.66 per cent (equivalent to 5.8 per cent Ti). The tailings from the treatment gave: Fe, 42.84 per cent; TiO_2, 32.22 per cent. A sample of the concentrates recrushed so as to pass through a 16 mesh screen and reconcentrated by hand showed the following percentages on analysis:

Fe	63
SiO_2	1.08
TiO_2	5.25
Al_2O_3	5.65

Another sample was crushed through a 40 mesh screen and subjected to separation under water with a hand magnet. Analyses of the concentrates are given below: No. 1 is by A. S. McCreath & Son, and No. 2 by P. W. Shimer.

	1	2
Fe	65.35	64.69
Mn	.186	.....
SiO_2	.14	.....
TiO_2	5.32	6.49
Al_2O_3	2.76	2.59
CaO	.05	.....
MgO	.76	.....
P	.012	.0045
S	.041	.....

While it would scarcely be practicable, perhaps, to crush the ore to a size that would permit a reduction of the titanium to the

limits indicated in the last analyses, there would appear to be no difficulty in the way of preparing concentrates with an average of 8 or 10 per cent TiO_2. The loss of iron in the tailings is the only drawback to concentration, but in the case of immense deposits like those at Lake Sanford which can be worked very cheaply this could hardly be critical.

The electric furnace has been suggested for titaniferous ores, yet the expense of making iron by this method must operate against its extended use so long as coke is available at anything like present prices. The open-hearth method of steel manufacture seems to offer a field that is worthy of investigation. Crude ores are employed now quite largely in the process instead of scrap metal. From what can be learned it appears that the use of titaniferous ores for that purpose has not been experimented with to any extent.

LAKE SANFORD DEPOSITS

This group of ore bodies, undoubtedly the most important of the kind in the Adirondacks, is situated in Newcomb township, western Essex county, on the slope of the rugged mountain complex that has Mt Marcy as its central and culminating point. Lake Sanford is the largest of several lakes in the vicinity which form the head waters of the Hudson. The site of the former Adirondack village (now occupied by the Tahawus Club) which was built by the early iron workers, lies in the midst of a wild, heavily forested region, shut in by high elevations on all sides except the south where the river has worn a narrow valley. North Creek, the terminus of the Adirondack branch of the Delaware & Hudson Railroad is about 30 miles distant by wagon road, and Port Henry on Lake Champlain about 50 miles. The ore bodies outcrop at elevations ranging from 1800 to about 2100 feet above sea level. Their distribution is indicated on the accompanying map which reproduces a part of the Santanoni quadrangle of the United States Geological Survey [pl. 15]. The scale of the map is 1 mile to the inch.

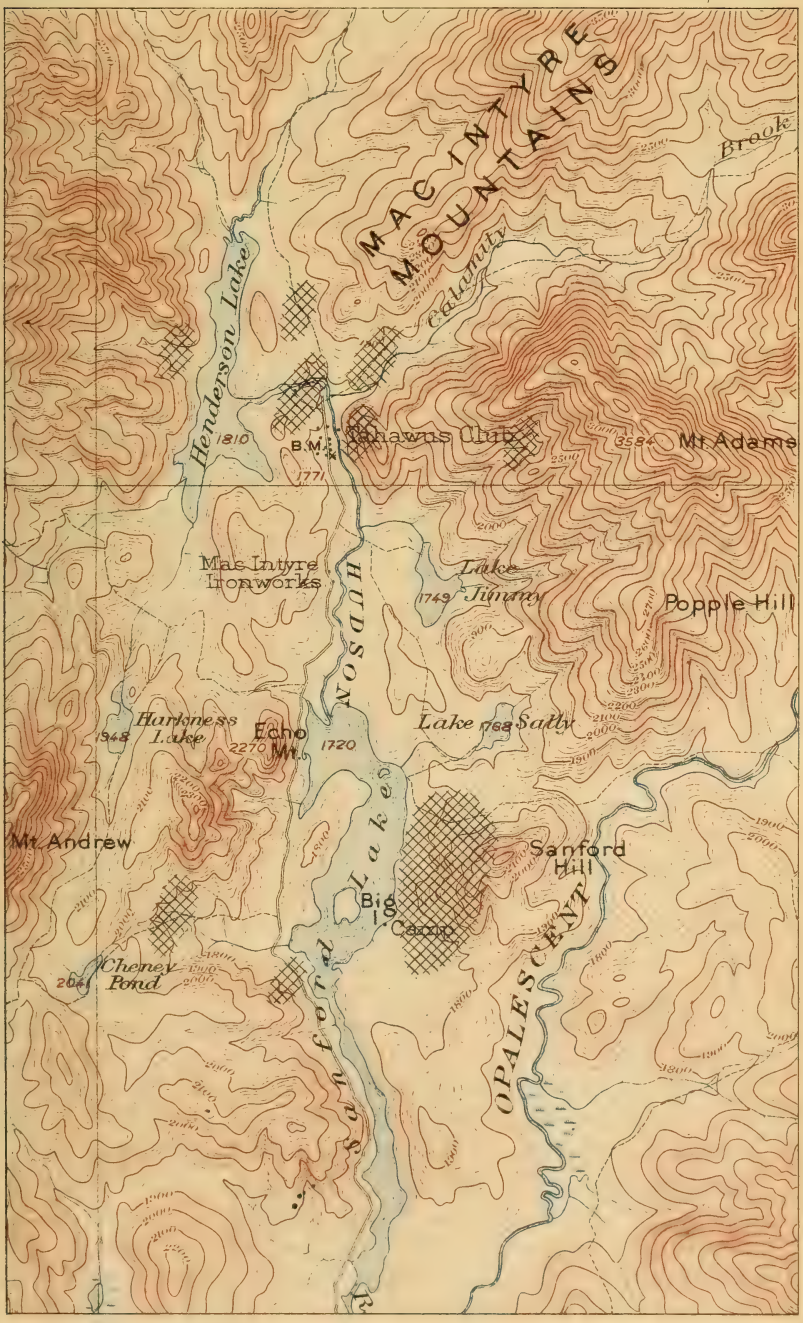
Unusual interest attaches to the events connected with the first development of the Lake Sanford deposits and the establishment of the local iron-making enterprise to utilize the ores.[1] Following

[1] A good historical account of the discovery and exploitation of the deposits will be found in Watson's "History of Essex County." The reports by Emmons contain a description of developments up to 1840. For details as to the blast furnaces and metallurgical operations consult Rossi, "Titaniferous Ores in the Blast Furnace." Am. Inst. Min. Eng. Trans. v. XXI. 1892–93.

the discovery, which is reported to have been made in 1826, a tract of land comprising the deposits was secured from the State by Mr A. McIntyre and associates who soon after began active work. The investigations of Professor Emmons in connection with the Geological Survey of New York then in progress no doubt gave a stimulus to the undertaking. Professor Emmons published in his reports an extended account of the ore bodies which he recognized to be of enormous size and regarded as eminently adapted to utilization. He recommended the location of iron-manufacturing enterprises in the vicinity. Soon after the publication of his first report, or about 1840, a blast furnace of three or four tons daily capacity was built and placed in operation. This was afterward remodelled so as to enlarge its capacity, and a second furnace of 12 to 15 tons was put in blast in 1854. Drawings of the large stack which remains to the present day with all its essential features have been made by Mr Rossi and published in the article already referred to. The installation included also puddling furnaces and the necessary equipment for making bar iron. The works were closed down in 1856, after which they were not again operated for any length of time. The product of the furnaces was hauled over a difficult mountain road to Crown Point for shipment, and the expense of transportation must have been a heavy tax upon the enterprise.

There seems to be little doubt, judging from all accounts, that the iron turned out in the early days was of good quality; in fact it was specially commended by Emmons and others; nor does it appear that the sudden termination of iron making was due to metallurgical difficulties in reducing the ore, though it is probable that the operators, at least in the early years, were unaware of the titaniferous character of the material. From considerations based on an analysis of slag which was taken from the dump near the old furnace, Mr Rossi has expressed the opinion that the furnace charges were made up on somewhat different lines than usually practised, in that a proportion of the country rock (anorthosite) was added to the limestone for flux. It may be noted, however, that the crude ore, such as was employed in the operations, contains more or less of admixed rock, so that the presence of the latter may have been accidental rather than intentional.

After lying idle for 50 years the property was taken over in 1907 by a new organization, the Tahawus Iron Ore Co., with a view to the exploitation of the ores. This company has conducted a thorough investigation and intends to enter upon active mining in the near future. The construction of a railroad is a requisite before commercial shipments can be made.



PART OF SANTANONI QUADRANGLE

MAP OF THE VICINITY OF LAKE SANFORD

Ore bodies are indicated by cross-hatching

Geology. The district lies within the main anorthosite area, but not far from its western bounds. As delimited in the preliminary survey of J. F. Kemp,[1] the gneiss series occupies approximately the western half of Newcomb township, the line of contact with the anorthosite which extends over the eastern half trending somewhat west of north. It is not easy to fix accurately the limits of the formations owing to the drift which chokes the valleys and reaches well up the slopes of the ridges. Anorthosite has been found by the writer to outcrop on Santanoni mountain, about 5 miles directly west of Lakes Sanford and Henderson, so that it probably continues in unbroken mass that far. The gneiss series first appears on the shores of Newcomb lake and in the east-west valley occupied by Rich and Harris lakes, whence it stretches westward as far as the confines of the Adirondacks.

The gneiss series bordering the anorthosite has been subjected only to a cursory examination. Apparently it consists of a complex in which both sedimentary and igneous types are represented. The former have particularly strong development around Newcomb, where there is one of the largest Grenville exposures in the interior of the Adirondacks. They comprise the usual rusty micaceous and hornblendic gneisses and schists, with interfolded belts of crystalline limestone carrying graphite and other characteristic minerals. A limestone ledge on the east side of Newcomb lake was a source of flux for the early furnace operations. Professor Cushing in his recent mapping of the geology of the Long Lake quadrangle has noted the presence of extensive masses of syenite and granitic gneisses, and it is not unlikely that upon further investigation they will be found to constitute an important part of the area farther east along with the Grenville formation. The region about the mines is included in the Santanoni quadrangle which adjoins the Long Lake sheet on the east.

The principal interest in connection with the iron ores is attached, of course, to the anorthosite. Where exposed near the mines this is generally a very typical variety of the rock as developed in the Adirondack region. It consists essentially of labradorite in grayish or bluish black crystals, that occasionally exhibit a play of colors on cleavage surfaces. The crystals are generally large, up to 3 or 4 inches in length, and are closely interwoven with a coarsely granitic texture. While as a rule the feldspar constitutes practically the only mineral observable in hand speci-

[1] Preliminary Report on the Geology of Essex County. N. Y. State Mus. 49th An. Rep't. 1898. 2:604.

mens, the microscope reveals the presence of augite and hypersthene in small amounts and usually some magnetite or ilmenite. In portions of the mass that show effects of crushing in the breaking down or mashing of the feldspar, there is found a development of secondary minerals such as garnet, biotite and calcite. The garnet has a tendency to form aggregates about the magnetite, which owing to their red color stand out plainly from their surroundings. The mineral has drawn upon the magnetite for the iron and the feldspar for the lime and silica necessary to its growth. Biotite is not so common as the garnet with which it is closely associated and no doubt genetically related. The following analysis, quoted from a paper by Prof. Albert R. Leeds, will serve to show the chemical character of the anorthosite. The sample from which it was made was taken from the summit of Mt Marcy.

SiO_2	54.47
Al_2O_3	26.45
Fe_2O_3	1.3
FeO	.66
CaO	10.80
MgO	.69
K_2O	.92
Na_2O	4.37
H_2O	.53
	100.19

In places the typical anorthosite, as above described, gives way to a much finer grained rock in which the pyroxene minerals are more prominent, showing a transition to gabbro. With this mineralogic change the feldspar individuals decrease in size and number and the color becomes greenish. Such phases are apt to have a gneissoid texture as they are less resistant to metamorphic influences than the anorthosite, a feature that is illustrated as well by the development of hornblende in the place of the pyroxene minerals and of abundant garnet. They are undoubtedly a differential product of the anorthosite, but it is not always clear whether the gabbro has separated in place or has come up through the anorthosite in the form of dikes.

Ore bodies. Ore is found in both the anorthosite and the gabbro. The anorthosite is the commoner wall rock and the ore bodies which it incloses have perhaps the greater possibilities for commercial utilization, due to their uniform character and higher average of

Plate 16

Blast furnace at Lake Sanford, once used on the titaniferous magnetites. Built in 1853

iron. They are also coarser grained as a rule than the ores in the gabbro.

The deposits outcrop on both sides of the narrow valley occupied by Lakes Sanford and Henderson and their outlet which is one of the head-streams of the Hudson river. The valley bottom lies at an elevation of from 1700 to 1800 feet. The situation of the more important ore bodies is shown on the map reproduced from a section of the Santanoni quadrangle [pl. 15]. The outlines of the bodies as sketched are to be considered as approximations only, since they have not been fully proved. It will be observed that the deposits are grouped along a north-south belt about 2 miles wide and 4 or 5 miles long.

On the south end are the Sanford and Cheney ore bodies situated on the east and west sides respectively of Lake Sanford. The Sanford is perhaps the most important of the whole group. It lies between the crest of Sanford hill and the lake shore, occupying in its widest part the entire interval of about $\frac{1}{4}$ mile and running north and south for fully twice the distance. Outcrops are found on the west shoulder of the hill, at a point about 300 feet above the lake level where a small quantity of ore has been removed, and at many points directly south. For the most part the outcrop is concealed, however, by a light covering of soil and glacial materials. The Sanford deposit was prospected with considerable care by Professor Emmons who has left a circumstantial and faithful record of the results.[1] Five lines of excavation were made under his direction, four running transverse and one parallel to the length of the body. The middle transverse section began at the base of the hill and ran eastward at right angles to the course of the ore, a distance of 514 feet. Its exact location is not now ascertainable though probably it was about on a line with the opening mentioned above. The record of this section which is given in greatest detail affords a good idea as to the general character of the ore body and is here quoted.

Record of the middle transverse section of the Sanford ore body made by Professor Emmons

Pit no.	Interval feet	
1	..	Fine granular feldspar, intermixed with iron, garnet and hornblende
2	36	Rich ore breaking into tabular masses

[1] Survey of the Second Geological District. 1842. p. 249.

Pit no.	Interval feet	
3	10	Rich ore, as above
4	15	Rich ore
5	20	Rich ore, mixed in a small proportion with granular feldspar
6	12	Granular feldspar in a decomposing state containing only a small proportion of ore
7	20	Rich ore, mixed with a few scales of black mica and feldspar
8	22	Rich ore, mixed with garnet and feldspar
9	24	Nearly the same as No. 8, but brighter
10	24	Rich ore, with a very small portion of feldspar
11	22	Loose decomposed rock
12	17	Rich ore
13	15	Rich ore, with feldspar
14	39	Rich granular ore, with a resinous luster
15	15	Lean ore
16	22	Principally rock
17	28	Pure ore
18	35	Pure ore
19	36	Rich ore
20	22	Pure ore
21	27	Pure ore
22	30	Pure ore
23	29	Pure ore
24	30	Ore mixed with garnet
25	14	Rock mixed with particles of ore

The other sections are not so detailed but show about the same relations. Section No. 2 was run 268 feet south of No. 1 or middle section and gave a width of 610 feet of ore without apparently encountering the walls. Section No. 3 crossed the ore body 210 feet south of No. 2, and No. 4 was run 231 feet north of No. 1; their length is not stated. On the basis of this work Professor Emmons estimated the ore body to contain 6,830,000 tons at a depth of 2 feet below the adjoining surface. The results obtained by diamond drilling during the years 1906 and 1907 have demonstrated that the ore continues westward practically to the lake side considerably farther than Emmons was able to trace it, while they have also proved its continuity to a depth of 300 or 400 feet, as far as the drills have penetrated. Recent magnetic surveys show the existence of lines of attraction which cross the lake to the western shore where they merge with the smaller ore body

which outcrops just south of Big island as indicated on the map. The latter is thus probably an extension of the Sanford, the two being connected by a belt beneath the lake.

The Sanford deposit is conveniently situated for working, and a quantity of ore that is not subject to careful estimate but which must amount to several millions of tons can be removed by ordinary quarry methods before reaching the level of the adjacent lake. Its position directly in the valley will facilitate transportation when once the district is provided with railroad communication. In quality the ore is above the average of the district. Except for admixture with feldspar it is nearly a pure aggregate of iron minerals. The feldspar is segregated to a great extent along certain bands, though it occurs in smaller amount all through the mass. The separation of the rich ore from the admixed ore and rock could be performed without much difficulty during the quarry operations.

The Cheney deposit lies about a mile west of Lake Sanford, and has apparently no connection with the Sanford body. It is known to be of large size, though it has been little explored. In one place a pit of some 20 feet deep has been opened. Professor Kemp has described the occurrence as follows: "The wall rock is a gabbro-gneiss as already stated, and the ore contains more sulfur and phosphorus than do the others in the anorthosites. It emits a sulfurous odor when broken with the hammer. In thin sections it is seen to be lean. Apatite is abundant, and brown hornblende, red brown biotite, chloritized augite, and some plagioclase make up a large part of the aggregate." The ore is at times quite rich, but its average is not as high as the Sanford ore.

About 2 miles north of the Sanford deposit, on its line of strike, there is an exposure of fine grained ore which is mentioned by Emmons as a probable continuation of that deposit. There is said to be a nearly continuous line of magnetic attraction between the two. An opening has been made well up on the side of Mt Adams. In addition to plagioclase the ore, according to Kemp, contains some spinel.

In the vicinity of the Tahawus Club and north and west of there towards Lake Henderson, there is a complex of deposits forming an almost connected series distributed over an area of perhaps a square mile. Ore shows on both sides of the river near the outlet of Calamity brook, and on the west side is the Millpond opening from which most of the ore in the early days was taken to supply the furnace. This pit is about 100 feet long and from 10 to 40 feet wide, the walls are like those of the Sanford deposit and the iron

made from it was highly commended by Professor Emmons. It was used without concentration. The so called "iron dam" is a dike of ore which cuts across the river back of the Tahawus Club in a northeasterly direction. It has a width of 10 feet or a little more, but includes a good deal of feldspar.

Along Calamity brook, beginning a short distance from the outlet, ore is exposed for a distance of 500 or 600 feet and can be traced to the west for several hundred feet. It is mostly a fine grained intimate mixture of iron minerals and feldspar, pyroxene and garnet. In the leaner phases it is a ferriferous gabbro. It would appear that this ore occurrence, as well as others of this type, represents an intrusion of a highly ferriferous gabbro in the anorthosite. This ore contains considerable pyrite and is consequently quite sulfurous. The magnetite is in part concentrated in small stringers or veinlets which intersect the gabbro in all directions.

Between the latter locality and Lake Henderson there has been uncovered by the exploratory operations conducted during the last two years an important ore-bearing area that seems to have been overlooked in the earlier investigations. No mention of the occurrence is made by Emmons or Kemp. The tract is heavily wooded and covered with a stratum of soil and glacial boulders. By excavating a line of trenches, ore has been shown to exist in practically a continuous body, the bounds of which have not yet been determined. The ore ranges from an almost solid mixture of magnetite and ilmenite to leaner material in which labradorite predominates. The deposit has been tested in several places with the diamond drill, of which one of the records is here given.

	Feet	Inches
Lean ore, consisting of disseminated magnetite with feldspar and pyroxene	19	3
Rich ore	30	6
Rock and lean ore, alternating	15	....
Rich ore	33	6
Rock carrying some ore	11	1
Lean ore	12	....
Rock and lean ore	8	....
Rich ore alternating with seams of rock	10	7
Rock	5	....
	144	11

Character of the ores. The difference in character of the Lake Sanford ores depending upon their geological associations has

Valley between Lake Sanford and Lake Henderson; looking north. Ore bodies outcrop in the middle distance and on the ridges to the left and right

already been noted. The ores which have anorthosite for walls are more uniform than the others in their physical appearance and mineralogy, and also appear to be somewhat richer in iron. As a rule they are coarsely textured; the constituent grains of magnetite have a mean diameter of $\frac{1}{4}$ to $\frac{1}{2}$ inch. When free from feldspar they can scarcely be distinguished in hand specimens from the nontitaniferous magnetites. Variations in granularity can be noticed in different parts of the same ore body, but the grain seldom approaches the fineness of the ores included by the gabbro. With the exception of inclusions of labradorite and occasional crystals of pyroxene, they are remarkably pure ores. The ores found in the gabbro usually carry these minerals in quantity, as well as garnet and small amounts of pyrite and apatite. Their texture approaches that of a normal gabbro, owing to the presence of the silicates, and they are very dense and tough.

The following analyses furnish particulars as to the chemical composition of the ores from the principal deposits. They have been obtained from the papers by Kemp and Rossi, except Nos. 5 and 11 which have been communicated by Mr W. L. Cumings and No. 6 which was made by Prof. E. W. Morley from a sample gathered by the writer.

	Sanford deposit					
	1	2	3	4	5	6
Fe_3O_4.....	70.80	71.03	70.73	87.60	.....	[a]83.4
SiO_2.....	1.39	1.34	2.46	.87	2.09	.....
TiO_2.....	19.52	18.70	20.03	10.91	9.45	14.
Al_2O_3.....	4.00	.....	3.50	.53	.....	.....
P.....	.022	.....	.....	.....	.007	.....
S.....	.028	.....	.....	.....	.027	.....
Iron.....	51.30	51.44	51.22	62.65	63.36	60.5

	Millpond pit			Cheney pit		Iron dam
	7	8	9	10	11	12
Fe_3O_4.....	87.20	82.37	73.62	55.64	86.53	.....
SiO_2.....	1.09	3.67	1.53	9.79	.....	1.96
TiO_2.....	10.73	13.38	19.74	15.77	8.25	10.85
Al_2O_3.....	.44	1.50	3.50	7.12	.....	.....
P.....	nil	.017	.037	.....	.39	.008
S.....	nil	.068	.08	1.00	.74	.009
Iron.....	63.45	59.56	53.62	40.33	62.15	64.47

[a] Fe_2O_3 55.9; FeO 27.5.

Analysis No. 5 is of a sample taken across the face of the Sanford pit. The ore here is, no doubt, above the average for the whole deposit, and the first three analyses perhaps are more representative. It will be seen that aside from the Cheney pit all of the ores are low in phosphorus and sulfur and well within the requirements for Bessemer ores.

MOOSE MOUNTAIN DEPOSITS

Moose mountain is a prominent peak 3 miles north of Hammondville, on the edge of the central anorthosite area. The deposits occur on the shoulder of the peak, a little east of the summit, at an altitude of about 2000 feet, as nearly as can be determined. They were opened several years ago by the Crown Point Iron Co., in an experimental way, but only a few hundred tons of ore have been taken out. The trail to the mines leads up the eastern side of the mountain, following the brook which empties into Paradox creek below the outlet of Round pond. At the point where the trail branches off, the outcrops are of augite syenite, but this rock gives way a few hundred feet west to anorthosite, the contact being marked by a garnetiferous zone which seems to be a metamorphosed phase of the syenite. Near the deposits gabbro appears and forms the immediate country rock. It is doubtless a large intrusion in the anorthosite. It has a strongly gneissoid texture with much red garnet that has evidently formed at the expense of the feldspar, and hornblende as the main dark constituent.

The ore bodies consist of bands or lenticular masses striking about northwest and apparently dipping northeast. The main pit is perhaps 40 feet long and from 4 to 5 feet wide. The ore in its prevailing character is but an enriched portion of the gabbro averaging not more than 40 per cent in iron. The magnetite is finely divided and is intergrown with pyrite. At one pit specimens were collected which showed a more coarsely textured material above the average in richness. The deposits appear to be of small extent, judging from the limited areas of magnetic attraction surrounding them.

SPLIT ROCK MINE

Split Rock mountain, on which the mine of that name is located, is an offshoot of the Adirondacks forming the western shore of Lake Champlain for some distance between Westport and the village of Essex. It rises abruptly from the lake level as a series of

peaks of which the highest is a little over 1000 feet. The approach from the western side where it falls toward the Bouquet river is more gradual.

The mine openings are in the face of a cliff fronting directly on the lake just north of the little cove that is locally known as Snake Den harbor. They lie about 100 feet above the shore and consist of two drifts, 10 feet or so wide, which follow the ore back into the mountain for a short distance. The workings date back over 25 years, as Smock states in his report that no ore had been mined for six years previous to his visit. The concentrating works, erected on the lake shore below the mine, have fallen into decay or have been removed. A magnetic process was employed for separating the magnetite from the gangue.

The main mass of Split Rock mountain consists of light gray anorthosite, with local intrusions of gabbro. Both rocks show strong crushing effects, the former in the granulation of the labradorite which constitutes almost the entire mass, and the latter in its markedly gneissoid texture as well as a similar granulation of its constituents. Both contain secondary garnet. The gabbro in thin section is seen to be mainly composed of augite, hypersthene, brown hornblende, garnet and labradorite, with olivine and magnetite in subordinate amount. The hornblende is plainly a result of chemical reaction between the magnetite and the feldspar brought about by the dynamic metamorphism which the rock has undergone. An analysis of the gabbro quoted from the paper by Professor Kemp is given on page 148 of this report.

The deposits occur directly in gabbro of which there is a considerable area in the vicinity. The relation between the ore and wall rock is that of complete gradation, there being no line of demarcation whatever between the one and the other. The magnetite in the gabbro increases in proportion until it becomes the principal constituent; while there is a corresponding retreat of the silicates, the feldspar being the first to disappear. A peculiar feature revealed by examining thin sections is the occurrence of veinlets of magnetite that evidently are the fillings of rifts in the ore subsequent to its consolidation. The veinlets are minute, but they can be traced generally across the whole section, breaking through the silicate minerals as well as the inclosing magnetite. It would appear that there must have been a secondary infiltration of magnetite, perhaps from a fused portion of the body at depth. Another singular phenomenon, noted by Professor Kemp in the ore from

this locality, is the presence of a greenish glass which forms veinlets and incrustations of microscopic size, with inclusions of feldspar and magnetite.

The ore has a fine grain and is exceedingly hard and tough. When observed in hand specimens the general run seems to be fairly rich, but closer examination shows, even in the richest material, that there is a considerable proportion of gangue minerals, The latter are distributed in small particles through the magnetite in such a manner that it would prove difficult to make a satisfactory separation of the material for commercial purposes.

The following analyses, of which No. 1 is by W. F. Hillebrand and No. 2 by George W. Maynard, give the composition of the ore.

	1	2
Fe_2O_3	15.85	38.43
FeO	27.94	23.40
SiO_2	17.90	16.46
TiO_2	15.66	14.70
Cr_2O_3	.51	.....
Al_2O_3	10.23	.34
MnO	tr.	.23
CaO	2.86	3.54
MgO	6.04	2.13
P_2O_5	.04	.....
V_2O_5	.55	.....
CO_2	.10	.....
S	.14	.....
H_2O	1.33	.....
	99.15	99.23
Iron	32.82	32.59
Titanium	9.40	8.82

LINCOLN POND MINE

The Lincoln pond mine, locally called the Kent mine, is about 5 miles northwest of Mineville, not far from the highway leading to Elizabethtown. It consists of a pit about 75 feet long by 15 feet wide, with a shaft at one end of unknown depth. The wall rock is a massive hypersthene gabbro, carrying more or less garnet. The ore has the usual character of the magnetites found in this

association, though it is rather above the average in iron. It contains besides the silicates of the gabbro small crystals of apatite. An analysis by W. F. Hillebrand contained in Professor Kemp's paper shows the following percentages.

Fe_2O_3	30.68
FeO	27.92
Al_2O_3	6.46
SiO_2	11.73
TiO_2	12.31
CaO	3.95
MgO	3.35
K_2O	.26
Na_2O	.50
P_2O_5	.82
V_2O_5	.04
CO_2	.32
S	.04
C	.05
Cl	.12
Fl	tr.
H_2O	.64
	99.19
Iron	44.19

The presence of carbon is an interesting feature of the analysis and is probably due, according to Hillebrand, to the inclusion of graphite. Professor Kemp was unable to identify that mineral under the microscope beyond doubt, though a few black particles were observed in the chemical residues which might well have been of graphitic nature.

LITTLE POND MINES

A short distance north of Little pond, 2 miles south of Elizabethtown, two openings have been made in titaniferous bodies which appear to be of considerable size. The northern opening is about 20 feet across at the surface and 15 feet deep, while the other to the south has been excavated in the hillside and is about 30 feet long and 25 feet high at the working face. The walls consist of dark green gabbro. The ore is lean, as it carries a good deal of

garnet, hornblende, feldspar and the other constituents of the gabbro. Analyses by W. F. Hillebrand, quoted from Kemp's article, show the following composition for the ore from both pits.

	North pit	South pit
Fe_2O_3	26.30	11.16
FeO	29.78	28.35
TiO_2	18.82	13.07
Cr_2O_3	.75	.37
V_2O_5	.62	.50
P_2O_5	tr.	.32
S	.06	.10
	76.33	53.87
Iron	41.57	29.87

PORT LEYDEN MINE

Near the site of the old iron furnace at Port Leyden, Lewis co., a titaniferous ore body exists in somewhat remarkable associations. It was prospected many years since by a shaft which is said to be 65 feet deep but is now filled with water almost to the surface. No ore can be seen in place either at the shaft or in the outcrops nearby, so that it is probably limited to a lens or shootlike mass of no great lateral dimensions. In the volume of the *Mineral Resources* for 1886, the following mention is made of the occurrence: "A titaniferous ore at Port Leyden (Lewis county) occasioned the erection of a blast furnace, concerning which Mr George D. Colby says: 'With a view of ascertaining the amount and quality of the ore which led to the erection of these works, the present company made borings to a depth of 300 feet. The core of the borings indicated an abundance of ore, but of such chemical composition that no attempt has been made by this company to produce pig iron from it.' "

An analysis of the ore, quoted from the same source, shows the percentages below:

Fe_3O_4	52.67
FeS_2	5.86
SiO_2	10.95
TiO_2	9.31
Al_2O_3	5.21
Mn	1.12

CaO	8.38
P	2.59
S	3.12
	99.21
Iron	40.90

The analysis is perhaps of questionable accuracy in some respects. The sulfur is certainly all combined with the iron to form bisulfid, and the ferrous and ferric oxids can hardly be present in the exact proportions to form magnetite when there is such a large amount of titanium present as ilmenite. That the determinations of iron and titanium are substantially correct as to bulk, however, has been confirmed by an analysis made by Prof. E. W. Morley, on a sample gathered recently from the mine dump. The analysis gave: Fe 50.79 per cent; TiO_2 9.90 per cent.

The immediate walls of the deposit are not in evidence, but there are abundant outcrops in the vicinity, all of quartzose gneisses. The latter include a pink, slightly foliated variety and a grayish garnetiferous one. Both show under the microscope a composition that allies them to the granites and granitic gneisses of the Adirondacks. The feldspars are chiefly microperthite and microcline, though there may be a little acid plagioclase present. Quartz is abundant. The dark minerals comprise biotite and magnetite and a chloritic product that may have been derived from augite.

The ore is an extremely dense hard mass in which the magnetite occurs in finely divided particles intergrown with larger grains of pyrite. Biotite and garnet are also present. Some specimens taken from the dump at the shaft show inclusions of a green feldspar rock resembling the Adirondack syenite in composition and appearance.

The derivation of the deposit is difficult to explain except that it may be related to some underlying magma from which the ore body represents an offshot, perhaps intrusive in the granitic gneiss. The association of syenite alluded to affords evidence of the existence of such a magma, and it is well known that the gabbros and syenites and the granites in some cases as well grade into each other and are closely connected in their genesis.

OTHER TITANIFEROUS DEPOSITS

In the town of Westport, about 2 miles south of Westport village, several pits have been excavated in deposits that outcrop

on a ridge in contact with a gneissoid gabbro. They are of small size and the ore is lean.

Tunnel mountain, southeast of Elizabethtown and directly east of Little pond, carries a deposit which outcrops on the summit and has been opened to a depth of 40 or 50 feet. The pit runs about north and south and is 10 feet wide. An attempt was made to tap the deposit by a tunnel some 200 feet below the outcrop, but was given up before reaching the ore. An analysis of the ore by Hillebrand gave the following percentages:

Fe_2O_3	20.35
FeO	28.82
SiO_2	13.35
TiO_2	16.45
Cr_2O_3	.55
Al_2O_3	8.75
CaO	2.15
MgO	6.63
P_2O_5	.02
V_2O_5	.61
CO_2	.17
S	.09
C	tr.
Cl	tr.
H_2O	1.68
	99.62
Iron	35.99

On the east slope of Tunnel mountain two small pits have been excavated in lean titaniferous ore.

The Humbug vein, north of Cook shaft, Mineville, is titaniferous and probably occurs in gabbro, though its associations have not been fully determined. The ore is reported to carry 20 per cent TiO.

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New York State Education Department

New York State Museum

JOHN M. CLARKE, Director

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Geologist's annual reports 1881–date. Rep'ts 1, 3–13, 17–date, O; 2, 14–16, Q.

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Museum bulletins 1887–date. O. *To advance subscribers, $2 a year or $1 a year for division (1) geology, economic geology, paleontology, mineralogy; 50c each for divisions (2) general zoology, archeology and miscellaneous, (3) botany, (4) entomology.*

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4	54, v.4	4	" v.4	12, 13	" v.4	6	55, v.1
5	56, v.1	5, 6	55, v.1	14	55, v.1	7	56, v.4
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7	50, v.1	Z 3	53, v.1	Bo 3	52, v.1	*Memoir*	
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